PB82-231093

Industrial Boiler Combustion Modification NOx Controls. Volume III: Stoker-Coal-Fired Boiler Field Test - Site B

Acurex Corp.
Mountain View, CA

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

Jul 81

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

EPA-600/7-81-126c

July 1981

Research and Development

PB82-231093

INDUSTRIAL BOILER COMBUSTION MODIFICATION NO_x CONTROLS

Volume III. Stoker-coal-fired Boiler Field Test--Site B

Prepared for

Office of Air Quality Planning and Standards

Prepared by

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/7-81-126c

2.

3. RECIPIENT'S ACCESSION NO. PB82-231093

4. TITLE AND SUBTITLE Industrial Boiler Combustion Modification NOx Controls; Volume III. Stoker-Coal-Fired Boiler Field Test--Site B

5. REPORT DATE July 1981

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S) H.I. Lips and E.B. Higginbotham

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Acurex/Energy and Environmental Division
485 Clyde Avenue
Mountain View, California 94042

10. PROGRAM ELEMENT NO. EHE624A

11. CONTRACT/GRANT NO. 68-02-2160 and 68-02-3176, Task 12

12. SPONSORING AGENCY NAME AND ADDRESS
EPA, Office of Research and Development
Industrial Environmental Research Laboratory
Research Triangle Park, NC 27711

13. TYPE OF REPORT AND PERIOD COVERED Task Final; 7/78-7/79

14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES IERL-RTP project officer is Joshua S. Bowen, Mail Drop 65, 919/541-2470.

16. ABSTRACT The report gives methods and results of an environmental assessment test program at an industrial site. The aim of the program was to measure multimedia emissions changes as a result of applying NOx controls. Emissions of trace elements, organic materials, sulfur species, SO2, NOx, CO, and particulate matter were measured. These emissions, under normal and controlled (for NOx) were compared. Source operating data were also analyzed so that changes in operating parameters and efficiency could be assessed. This unit is a 91 Mg/hr (200,000 lb/hr) steam traveling-grate spreader-stoker coal-fired boiler, in service about 5 years. The fuel tested is low-sulfur coal. Low excess air (LEA) firing was sued for NOx control. These measures reduced NOx to 43% of baseline levels, although 10-25% reductions are considered typical for LEA. The reduced excess air level also gave a slightly improved boiler efficiency. These were 5-hour tests; long-term operation under test conditions was not addressed in this program. Test results show that applying combustion modification NOx controls did not affect total particulate emissions from the ESP outlet or sulfur species emissions. Some changes in trace element partitioning occurred with the application of NOx controls. Bioassays of ash samples for LEA operation had low or nondetectable toxicity/mutagenicity.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Boilers	Stationary Sources	13A
Combustion Control	Industrial Boilers	21B
Nitrogen Oxides	Combustion Modification	07B
Stokers	Spreader Stokers	
Coal	Traveling Grates	21D

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 205
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

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EPA 600/7-81-126c
July 1981

INDUSTRIAL BOILER COMBUSTION MODIFICATION NO_x CONTROL
VOLUME III: STOKER COAL-FIRED BOILER FIELD TEST SITE B

by

H. I. Lips and E. B. Higginbotham

Acurex Corporation
Energy & Environmental Division
485 Clyde Avenue
Mountain View, California 94042

Contract No. 68-02-2160
Acurex Project 7245
Acurex Final Report FR-81-83/EE

Project Officer

J. S. Bowen
Combustion Research Branch
Energy Assessment and Control Division
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina 27711

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

ABSTRACT

This test report describes the methods and results of an environmental assessment test program conducted at an industrial site. The purpose of the test program was to measure changes in multimedia emissions as a result of applying NO_x controls. Emissions of trace elements, organic materials, sulfur species, and the criteria pollutants, SO_2, NO_x, CO and particulate matter, were measured. Comparisons of these emissions under normal operating conditions and controlled (for NO_x) operating conditions were then made. Source operating data were also analyzed so that changes in operating parameters and efficiency could be assessed.

This unit is a 91 Mg steam per hour (200,000 lbs. steam per hour) traveling grate spreader stoker coal-fired boiler. This boiler has only been in service about five years. The fuel tested is a low sulfur coal.

Low excess air firing (LEA) was used for NO_x control. These measures achieved NO_x reductions of 43 percent from baseline levels, although 10 to 25 percent reductions are considered typical for LEA. The reduced excess air level also gave a slightly improved boiler efficiency. These were, however, 5-hour tests. Continuous operation under the test conditions was not addressed in this program.

The test program concludes that applying combustion modification NO_x controls did not affect total particulate emissions from the ESP outlet or sulfur species emissions. Some changes in trace element partitioning occurred with the application of NO_x controls.

Bioassays tests were also conducted on ash samples from LEA operation. These samples were found to have low or nondetectable toxicity or mutagenicity.

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Grube

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ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of Mr. Vernon Hines and the power plant staff at Site B. Also the authors wich to acknowledge the assistance of Messrs. P. L. Langsjoen and J. E. Gabrielson of KVB and the KVB Site B field testing crew in this cooperative testing effort.

SECTION 1
INTRODUCTION

This report is part of a series of test reports resulting from the experimental testing task of the "Environmental Assessment of Stationary Source NO_x Control Technologies" (NO_x EA), Environmental Protection Agency (EPA) contract 68-02-2160. The NO_x EA is a 3-year program to: (1) identify the multimedia environmental impact of stationary combustion sources and combustion modification NO_x controls; and (2) identify the most cost-effective environmentally-sound NO_x controls for attaining and maintaining current and projected NO_2 air quality standards to the year 2000.

During the first year of the NO_x EA a preliminary environmental assessment concluded that emissions and operating data needed to perform adequate process engineering and environmental assessment activities were severely lacking in several key areas. Most noteworthy was the virtual absence of data on noncriteria flue gas emissions and liquid and solid effluents (Reference 1). In response to these identified data needs, NO_x EA field test programs were initiated. Source selection was based on a source/control priority listing developed in the preliminary environmental assessment. These test programs were designed to provide information on changes in emissions and operation due to NO_x controls. The NO_x EA field test program is outlined in Table 1-1.

The test program documented in this report was conducted on an industrial spreader stoker producing 25 kg/s steam (200,000 lb steam per hour). This design is typical of a large segment of the coal-fired industrial boiler population. Through the cooperation of the industrial user, this unit was made available for testing the NO_x EA field test program. This unit has also been tested by others and their test results are described in References 2 and 3.

TABLE 1-1. NO_x EA FIELD TEST PROGRAM

Source Category	Description	Test Points (Unit Operation)	Sampling Protocol	Test Collaborator	Status
Coal-fired Utility Boiler	Kingston #6; 180 MW tangential; twin furnace, 12 burners/furnace, 3 elevations; cyclone, 2 ESP's for particulate control	Baseline Biased Firing (2) BOOS (2)	Continuous NO_x, SO_2, CO CO_2, O_2 Inlet to 1st ESP: -- SASS -- Method 5 -- Method 8 -- Gas grab (C_1-C_6 HC) Outlet of 1st ESP: -- SASS -- Method 5 -- Method 8 -- Gas grab (C_1-C_6 HC) Bottom ash Hopper ash (1st ESP, cyclone) Fuel Operating data	TVA	Complete August 1977
Coal-fired Utility Boiler	Crist #7, 500 MW opposed wall fired; 24 burners, 3 elevations; ESP for particulate control	Baseline BOOS (2)	Continuous NO_x, CO, CO_2 O_2 ESP inlet -- SASS -- Method 5 -- Method 8 -- Gas grab (C_1-C_6 HC) ESP outlet -- SASS -- Method 5 -- Method 8 -- Gas grab (C_1-C_6 HC) Bottom ash ESP hopper ash Fuel Operating data Bioassay	Exxon	Complete June 1978

TABLE 1-1. Continued

Source Category	Description	Test Points (Unit Operation)	Sampling Protocol	Test Collaborator	Status
Oil-fired Utility Boiler	Moss Landing #6; 740 MW opposed wall fired; 48 burners, 6 elevations	Baseline FGR FGR + OFA	Continuous NO_x, CO, CO_2 O_2 SAS Method 5 Method 8 Gas grab (C_1-C_6 HC) Fuel Operating data Bioassay	New test start	Complete September 1978
Coal-fired Industrial	Traveling grate spreader stoker, 38 kg/s (300,000 lb/hr), ESP for particulate control; wet scrubber for SO_x control	Baseline LEA + High OFA	Continuous NO_x, CO, CO_2 O_2 Boiler exit: -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C_1-C_6 HC) ESP outlet -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C_1-C_6 HC) Bottom ash Cyclone hopper ash Fuel Operating data	KVB	Complete October 1977
Coal-fired Industrial	Traveling grate spreader stoker, 25 kg/s (200,000 lb/hr), ESP for particulate control;	Baseline LEA	Continuous NO_x, CO CO_2, O_2 Boiler exit: -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C_1-C_6 HC) ESP outlet -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C_1-C_6 HC) Bottom ash ESP hopper ash Fuel Operating data Bioassay	KVB	Complete February 1978

TABLE 1-1. Concluded

Source Category	Description	Test Points (Unit Operation)	Sampling Protocol	Test Collaborator	Status
Oil-fired Gas Turbine	T.H. Wharton Station, 60 MW GE MS 7001 C machine	Baseline Maximum water injection	Continuous NO_x, CO, CO_2 O_2 SASS Method 5 Method 8 Fuel Water Operating data Bioassay	General Electric	Complete, April 1978
Oil-fired Residential Heating Unit	Blueray low NO_x furnace, Medford, New York	Continuous Cycling	Continuous NO_x, CO, CO_2 O_2 SASS Method 5 Method 8 Fuel	New test start with EPA-RTP	Complete, November 1978

The NO_x EA field test program at this site consisted of a baseline (normal operation) test and a test under the low excess air operating mode. The test program results will be used in both process analysis and source assessment modeling, conducted as part of the environmental assessment and process engineering task of the NO_x EA.

SECTION 2

TEST SITE DESCRIPTION

The unit tested was a single pass Riley boiler equipped with a Riley spreader stoker. The unit has a continuous rating of 25 Kg/s steam (200,000 lb/hr) with a 2 hour maximum capacity of 28 Kg/s. The steam is produced at a pressure of 1.38 MPa (185 psig) and temperature of 533 K (500^0F). The boiler is also equipped with a flyash reinjection system. All the ash from the boiler hopper is reinjected and part of the ash from the mechanical collector (a VOP Design 104 Dynamic Centrifugal Collector) is also reinjected. An electrostatic precipitator (ESP) is used for final flyash control. The boiler is also equipped with an economizer. Figure 2-1 is a diagram of the boiler and Table 2-1 gives the designed operating characteristics.

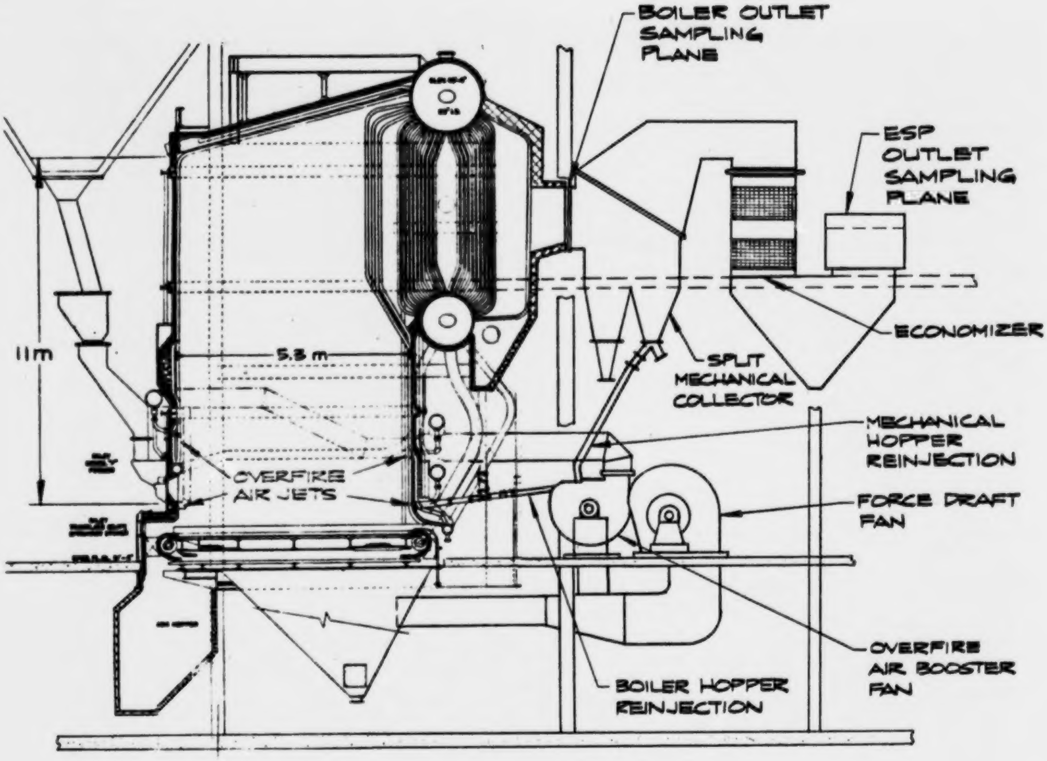
TABLE 2-1. DESIGN PERFORMANCE DATA WITH ECONOMIZER AND REINJECTION OF FLYASH[a]

Steam flow	25 Kg/s (200,000 lb/hr)
Blowdown	1.3 Kg/s (10,000 lb/hr)
Excess air in flue gas	31%
Boil exit gas temperature	583 K (590°F)
Economizer exit gas temperature	491 K (425°F)
Economizer exit water temperature	433 K (320°F)
Feed water temperature	397 K (255°F)
Ambient air temperature	300 K (80°F)
Steam quality	1 ppm
Steam temperature leaving boiler	533 K (500°F)
Superheater outlet pressure	1.38 MPa (185 psig)
Draft loss -- FD duct	220 Pa (0.87 in. H_2O)
Draft loss -- stoker grate	543 Pa (2.18 in. H_2O)
Draft loss -- boiler	331 Pa (1.33 in. H_2O)
Draft loss -- dust collector	785 Pa (3.15 in. H_2O)
Draft loss -- economizer	677 Pa (2.72 in. H_2O)
Draft loss -- electrostatic precipitator and ID duct work	436 Pa (1.75 in. H_2O)
Total FD draft loss	762 Pa (3.06 in. H_2O)
Total ID draft loss	2.23×10^4 Pa (8.94 in. H_2O)
Fuel	2.69 Kg/s (21,300 lb/hr)
Air	35.0 Kg/s (277,000 lb/hr)
Flue gas	37.5 Kg/s (297,000 lb/hr)
Overall efficiency	79.74%
Heat release -- projected furnace area	0.963 GJ/m^2 (84,900 Btu/sq ft)
Heat release -- furnace volume	0.762 GJ/m^2 (20,400 Btu/cu ft)
Heat release -- furnace width	44.6 MJ/m (12,900 Btu/ft)
Heat release -- Effective grate area	0.810 GJ/m^2 (713,000 Btu/ft^2)

---

[a] Based on assumed coal properties of

C - 72.3%
H_2 - 4.9%
S - 0.6%
Ash - 10.0%
N_2 - 1.2%
O_2 - 5.0%
H_2O - 6.0%
HHV - 28.8 MJ/kg (12,400 Btu/lb)


BOILER OUTLET SAMPLING PLANE
ESP OUTLET SAMPLING PLANE
ECONOMIZER
11m
5.8 m
SPLIT MECHANICAL COLLECTOR
MECHANICAL HOPPER REINJECTION
OVERFIRE AIR JETS
FORCE DRAFT FAN
OVERFIRE AIR BOOSTER FAN
BOILER HOPPER REINJECTION

34.4 m^2 EFFECTIVE GRATE AREA
365 m^3 FURNACE VOLUME
289 m^2 FURNACE AREA

Figure 2-1. Schematic of boiler.

SECTION 3
TEST PLAN

The objective of this test program was to examine incremental changes in emissions and process operations as a result of applying combustion modification NO_x controls. In order to assess incremental changes in emissions it was necessary to consider all influent and effluent streams. Process data were recorded periodically during each test so that changes in process operation could be examined.

3.1 UNIT OPERATION

This test program examined incremental changes in emissions and operations under low excess air operation and, for comparison, measured the same items for baseline of uncontrolled operation. Both tests were conducted at the same load, steam flowrate, and steam pressure.

The tests were conducted in February, 1978. Preliminary measurements were conducted on February 5, measurements under low excess air (LEA) conditions were made on February 6, 1978, and measurements under baseline conditions were made on February 7, 1978.

3.2 SAMPLING AND ANALYSIS

The sampling and analysis procedures used in this test program conform to a modified EPA Level 1 protocol (Reference 4). The purpose of these screening procedures is "to obtain preliminary environmental assessment information, identify problem areas, and provide the basis for prioritization of streams, components, and classes of materials for further consideration in the overall assessment. As such, the results of the sampling and corresponding analysis procedures are quantitative within a factor of ± 2 to 3" (Reference 4).

The modifications to the Level 1 protocol include:

- Atomic adsorption spectroscopy for selected trace elements instead of spark source mass spectrometry

- Specific ion electrodes for selected anions and ammonium ion instead of test kits
- Gas chromatography/mass spectrometry for specific identification and quantitation of polynuclear organic materials (POM).

These modifications were used to improve the quantitative aspects of the analyses. The methods used for particulate, sulfur species, and the continuous monitors for NO_x, O_2, CO, and CO_2, are also more quantitative than the Level 1 screening procedures for these species.

3.2.1 Sampling

In order to evaluate incremental changes in emissions, all influent and effluent streams with the exception of ambient air, were sampled and analyzed. The following samples were collected:

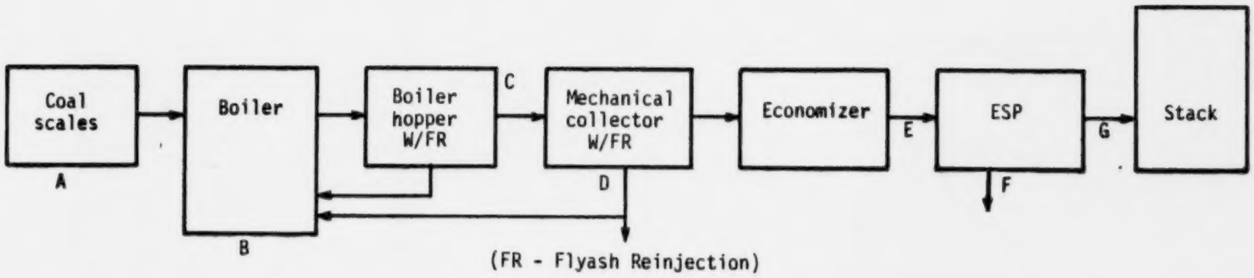
- Coal
- Bottom ash
- Mechanical collector ash
- ESP ash
- Flue gas
    - -- Continuous monitors for NO, CO, CO_2, O_2 at the boiler outlet and the economizer outlet
    - -- Source Assessment Sampling System (SASS), EPA Method 5 (particulate) and Shell-Emeryville Method (sulfur species) at boiler outlet and ESP outlet

A schematic showing sampling point locations is given in Figure 3-1. Descriptions of the sampling methods are given in the following paragraphs. Since each test required several hours to perform, it was important that the methods obtain samples representative of the entire test.

The SASS measurements were conducted by Acurex; continuous monitors, method 5, and Shell-Emeryville method measurements were made by KVB. The bioassays were performed by Litton Bionetics and Union Carbide Environmental Services.

Coal Samples

Coal samples were collected from each coal feeder serving the boiler. A grab sample from each coal feeder was collected periodically


Coal scales
A
Boiler
B
Boiler hopper W/FR
C
Mechanical collector W/FR
D
Economizer
E
ESP
F
G
Stack
(FR - Flyash Reinjection)

Sampling Location	Type of Sample
A - Coal scales	Grab sample - coal
B - Bottom ash hopper	Grab sample - bottom ash
C - Boiler outlet	Gas sample - continuous monitors, SASS, method 5, Shell Emeryville, gas grab for GC
D - Mechanical collector hopper	Grab sample - ash
E - Economizer outlet	Gas sample - continuous monitors
F - ESP hopper	Grab sample - ash
G - ESP outlet	Gas sample - SASS, method 5, Shell Emeryville, gas grab for GC

Figure 3-1. Schematic of sample point locations.

during the test. This composite sample was riffled on site, then ground and mixed with a representative sample being extracted for analysis.

Bottom Ash

Bottom ash sample collection was not started until the grate had traveled enough to remove most of the pre-test ash. This ensured that the bottom ash sample would come from the test period. Several samples were taken so a composite sample could be obtained.

Flue Gas Continuous Monitors

The continuous monitors for flue gas analysis were furnished by KVB in their mobile sampling van. The gas samples were taken continuously from points in the ductwork between the boiler outlet and the mechanical collector inlet. A second set of continuous monitors sampling ports were also located at the economizer outlet.

Flyash

Flyash collected by the mechanical collector and the electrostatic precipitator were sampled periodically during each test. These samples were taken from the collector hoppers at the same intervals as the coal was sampled so a composite sample was obtained.

Particulate and Sulfur Species

EPA Method 5 and Shell-Emeryville sampling trains were used to obtain particulate loading and sulfur species concentrations at the boiler outlet and the outlet of the electrostatic precipitator. The sulfur species determined were gaseous SO_2 and SO_3 (vapor phase sulfuric acid); particulate sulfate ($SO_4{=}$) was determined from the SASS samples. Sulfate ($SO_4{=}$) was also determined in the ash samples.

Source Assessment Sampling System

Two Source Assessment Sampling System (SASS) sampling trains were used simultaneously to sample the flue gas at the boiler outlet and at the electrostatic precipitator outlet. These samples were used for trace element and organic species determinations in both vapor and condensed phases and also to provide particulate size distribution and trace element partitioning information.

The SASS train extracts the following samples:

Particulate: >10 μm, 3-10 μm, 1-3 μm, <1μm
Vapor phase: XAD-2 porous polymer resin sorbent cartridge
Aqueous condensate

Hydrogen peroxide impinger

Ammonium persulfate-silver nitrate impingers

A schematic of the SASS train is shown in Figure 3-2. The analysis protocol followed is given in Appendix B.

C_1-C_6 Hydrocarbons

A gas grab sample was collected at the boiler outlet and at the outlet of the electrostatic precipitator. The sample was collected in a Tedlar bag and then used to determine C_1-C_6 hydrocarbon compounds by using an onsite gas chromatograph. A Carle model 8500 portable gas chromatograph with flame ionization detector was used for this analysis.

3.2.2 Analysis

Table 3-1 lists the analyses performed on the data and the samples collected during each test. Descriptions of these analyses are given in the following paragraphs. In cases or replicate tests, not all analyses were performed on all of the samples.

Operating Data Analysis

The unit operating data collected during each test was used to calculate unit efficiency and to verify that unit operating parameters were being maintained according to the test plan. The average values for the operating parameters are given in Appendix A. Since much of the panel board data was taken from instrumentation which had not recently been calibrated, these values should be regarded as relative rather than absolute. Unit efficiency was calculated using the Heat Loss Method, ASME Abbreviated Efficiency Test (Reference 5). Results of these calculations are given in Appendix A.

Inorganic Analyses

Trace element analyses for 23 selected trace elements were performed on fuel, bottom ash, mechanical collector hopper ash, ESP hopper ash, SASS flyash, and SASS impinger solutions. The procedure used for each trace element is outlined in Appendix B, "Elemental Analysis Flowsheet." Ash samples were also analyzed for selected anions; chloride, fluoride, nitrate, cyanide, and sulfate, plus ammonium as outlined in Appendix B, "Anions Plus Ammonium Analysis Flowsheet." Proximate and ultimate analyses were conducted on the fuel samples. Flyash was assayed for unburned combustible material.

TABLE 3-1. DATA AND SAMPLE ANALYSIS SCHEDULE

Test	Baseline	LEA
Operating data	X	X
Fuel		
Proximate and ultimate	X	X
Trace elements[a]	X	X
Bottom ash[a]		
Trace elements[b]		X
Carbon content		X
Bioassays		X
Organics		X
Mechanical collector ash		
Trace elements[b]	X	X
Carbon content	X	X
Organics	X	X
ESP hopper ash		
Trace elements[b]	X	X
Carbon content	X	X
Bioassays		X
Organics	X	X
Boiler outlet		
SASS train		
Trace elements[b]	X	X
Organics[c]	X	X
Method 5	X	X
Shell-Emeryville	X	X
Continuous monitors	X	X
ESP outlet		
SASS train		
Trace elements[b]	X	X
Organics[c]	X	X
Method 5	X	X
Shell-Emeryville	X	X

TABLE 3-1. Concluded

Test	Baseline	LEA
Economizer		
Continuous monitors	X	X

[a] Bottom ash sample available from LEA test only

[b] Trace elements and ionic species analyzed for include:

antimony
arsenic
barium
beryllium
bismuth
boron
cadmium
chromium
cobalt
copper
iron
lead
manganese
mercury
molybdenum
nickel
selenium
tellurium
thallium
tin

titanium
uranium (fuel only)
vanadium
zinc
zirconium (fuel only)
chloride
fluoride
cyanide
nitrate
sulfate
ammonium

[c] The following SASS train fractions were extracted and analyzed for organics: collected flyash; XAD-2 and condensate.

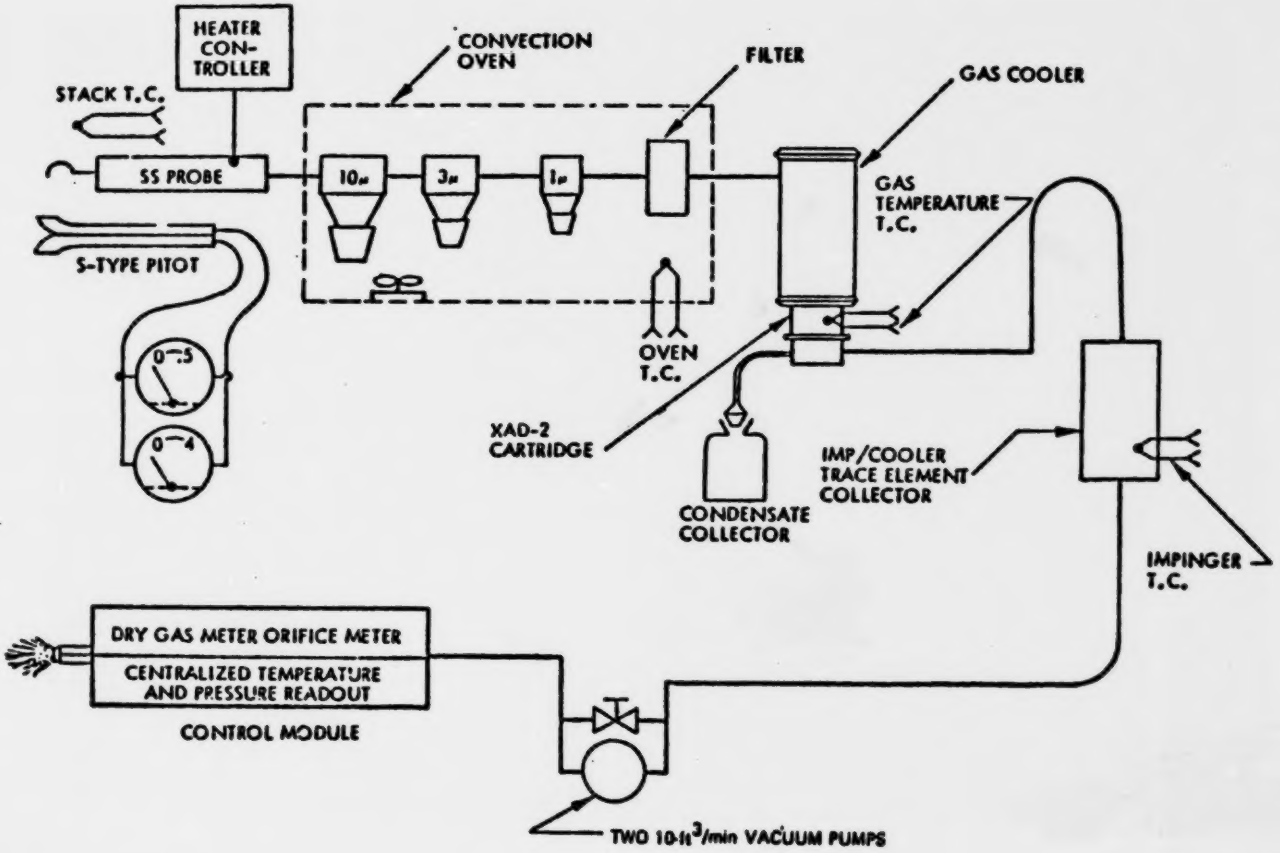

HEATER CON-TROLLER
STACK T.C.
SS PROBE
S-TYPE PITOT
0–.5
0–4
CONVECTION OVEN
10μ
3μ
1μ
FILTER
OVEN T.C.
GAS COOLER
GAS TEMPERATURE T.C.
XAD-2 CARTRIDGE
CONDENSATE COLLECTOR
IMP/COOLER TRACE ELEMENT COLLECTOR
IMPINGER T.C.
DRY GAS METER ORIFICE METER
CENTRALIZED TEMPERATURE AND PRESSURE READOUT
CONTROL MODULE
TWO 10-ft³/min VACUUM PUMPS

Figure 3-2. Source assessment sampling system (SASS) schematic.

Organic Analyses

Organic analyses were performed in accordance with the EPA Level 1 protocols (References 4 and 6). The analyses included flue gas C_1-C_6 hydrocarbons, organic material condensed on the ash samples, organic material condensed on the flyash samples collected by the SASS trains, and organic material caught in the XAD-2 sorbent trap or retained in the condensate trap. In addition to the above analyses, bioassays were performed on the bottom ash and ESP ash samples. An outline of the organic analyses procedures is given in Appendix B.

SECTION 4

TEST PROGRAM RESULTS

Data from the test program provided information on unit operation, flue gas composition, particulate emission, trace element emission, sulfur species emission, organic material emission, and toxicity of ash as determined by bioassays. Data obtained are discussed in the following sections.

4.1 UNIT OPERATION

Except for excess air level and related variables, unit operation was held essentially constant throughout the two tests. Key operating variables were controlled throughout the test program so that the two tests could be compared to each other. A summary of the boiler operating condition is given in Table 4-1. Detailed control room data for each test are presented in Appendix A. The data listed in Appendix A are average values of the data recorded at 30-minute intervals during the test program.

NO_x control consisted of lowering the excess air level. The excess air level is controlled by adjusting the combustion air feed rate. As measured at the boiler outlet, the excess oxygen level was reduced from 6.9 percent to 3.2 percent.

Table 4-2 gives the coal analysis results. As shown in the table the coal composition did not vary significantly between the tests. Thus, any changes in emissions measured from one test to the other should not be due to the coal composition variations.

Operating problems such as excessive clinker formation were not evident during the test program, Still, it must be emphasized that these tests were of 5 to 6 hour duration and cannot be considered indicative of extended operation.

Boiler efficiency for each of the tests was calculated using the abbreviated ASME efficiency method (Reference 5). The calculation results are given in Table 4-3 with more detail given in Appendix A. Note that,

TABLE 4-1. OPERATING CONDITIONS

Test	Steam Output kg/sec (10^3 lb/hr)	Steam Pressure MPa (psig)	Coal Flow kg/sec (lb/min)	Heat Input MW (10^6 Btu/hr)	Flue Gas Flow[a] dscm/GJ (dscf/10^6 Btu)	Excess Oxygen[a] %
Baseline	23 (182)	1.39 (137)	0.0402 (5.33)	73 (250)	434 (16200)	6.9
LEA	23 (183)	1.41 (190)	0.0398 (5.27)	75 (255)	317 (11800)	3.2

[a] Boiler outlet.

TABLE 4-2. COAL ANALYSIS (PERCENT BY WEIGHT)

	Baseline	LEA
Ultimate analyses		
Moisture	5.66	2.54
Carbon	73.03	75.11
Hydrogen	4.90	4.97
Nitrogen	1.36	1.38
Chlorine	0.07	0.07
Sulfur	0.79	0.81
Ash	6.87	7.48
Oxygen (diff)	7.32	7.64
Proximate analyses		
Moisture	5.66	2.54
Ash	6.87	7.48
Volatile	35.17	36.50
Fixed carbon	52.30	53.48
HHV MJ/kg	30.32	31.33
(Btu/lb)	(13,030)	(13,470)

TABLE 4-2. Concluded

Mineral Analyses	Percent Weight	Ignited Basis
SiO_2, Silica	43.3	50.2
Al_2O_3, Alumina	30.3	33.8
TiO_2, Titania	1.5	1.5
Fe_2O_3, Ferric oxide	12.8	6.6
CaO, Lime	2.7	2.4
MgO, Magnesia	1.0	1.0
K_2O, Potassium oxide	1.8	2.1
Na_2O, Sodium oxide	0.9	0.6
SO_3, Sulfur trioxide	3.1	2.1
P_2O_5, Phosphorus pentoxide	0.3	0.4
SrO, Strontium oxide	0.1	0.1
BaO, Barium oxide	0.3	0.2
Mn_3O_4, Manganese oxide	0.04	0.01

TABLE 4-3. BOILER EFFICIENCY

	Baseline	Low excess air
Heat input (percent baseline)	100	102
Excess O_2 (percent baseline)	100	46
Efficiency	79.9	81.6
Heat loss due to combustibles in ash (percent)	4.9	5.8
Heat loss due to dry flue gas (percent)	9.4	7.0

as expected, low excess air firing results in higher boiler efficiency. In both cases a large part of the efficiency loss is due to combustibles in the ash. It is difficult to do an ash material balance on a spreader stoker since several ash streams are not monitored and their flow rates must therefore be estimated. The value given for heat loss due to combustibles in the ash is then only an approximation.

4.2 FLUE GAS COMPOSITION

Table 4-4 lists the results obtained from gas sampling at the boiler and economizer outlets. As expected, NO_x levels did decrease under low excess air firing. However, the 43 percent decrease was more than the 10 to 25 percent usually associated with low excess air. Figures 4-1 and 4-2 present the variation in actual readings over each test.

In addition, the values reported for SO_2 may have large errors due to problems that KVB had when taking the SO_2 measurements. Because of this, no definite comment can be made about the SO_2 concentration in the flue gas. The measurements did indicate, though, that most of the sulfur in the flue gas was SO_2 rather than SO_3. The measured SO_2 level should be about 650 ppm at 3 percent O_2.

The effects of NO_x controls on CO emission cannot readily be assessed in this study. The boiler was operated such that CO excursions were not allowed. It can be said that this spreader stoker was operated under low excess air conditions without any increase in CO emissions.

4.3 PARTICULATE EMISSIONS

Particulate emissions were measured simultaneously at both the boiler outlet and the ESP outlet. These measurements were obtained by using EPA Method 5 and SASS techniques. EPA Method 5 employs multipoint equal area sampling to measure particulate concentration. The SASS train is used primarily to obtain samples for trace specie and organic analysis. In doing this, the SASS train provides particulate concentrations and size distribution data from a single point sample. Since this single point is a point of average flue gas velocity, the SASS sample should be representative of the average duct content.

Since the EPA Method 5 is a multipoint transverse of the duct while the SASS is a single point sample, the value obtained for total particulate loading by the EPA Method 5 would be more representative of the real value.

TABLE 4-4. FLUE GAS COMPOSITION AVERAGES

Test Probe Position	Baseline		Low Excess Air	
	Boiler Outlet	Economizer Outlet[a]	Boiler Outlet	Economizer Outlet[a]
O_2 (percent dry)	6.9	8.1	3.2	6.0
CO_2 (percent dry)	12.2	11.6	15.8	13.2
H_2O (percent)	5.7	5.4	6.7	6.4
CO (ppm at 3% O_2 dry)	48	65	31	36
NO_x (ppm at 3% O_2 dry)	321	343	182	215
SO_2 (ppm at 3% O_2 dry)	479[c]	267[b,c]	398[c]	142[b,c]

[a] Values listed under economizer outlet are averages of measurements made every two hours, while boiler outlet measurements were made about every 30 minutes.

[b] Measured at ESP outlet.

[c] SO_2 measurements may be in error (see Section 4.5).

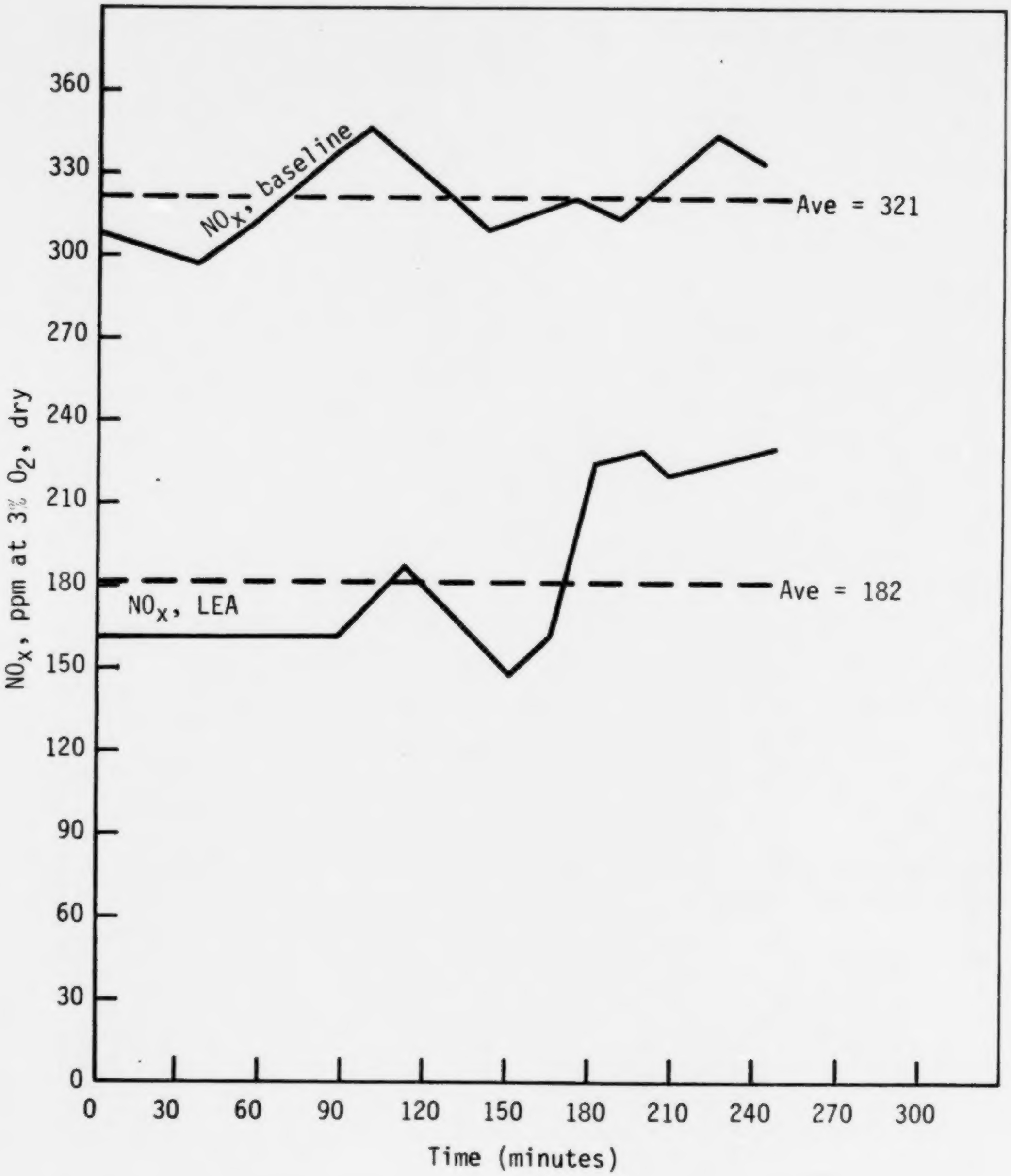


Figure 4-1. NO_x concentration at boiler outlet.

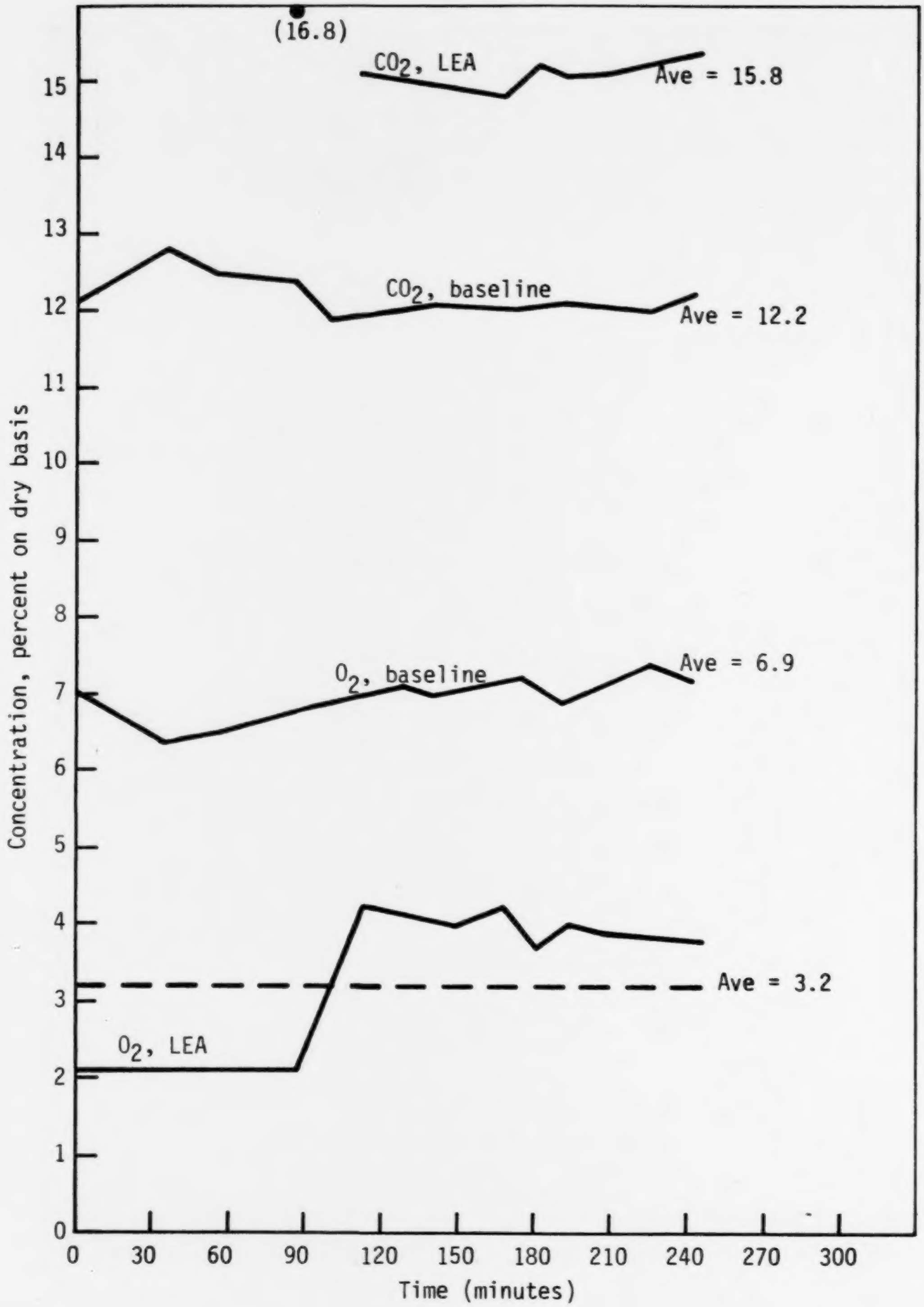


Figure 4-2. Flue gas concentrations at boiler outlet.

Simultaneous sampling at both the boiler outlet and ESP outlet will allow one to calculate the following information:

- Particulate concentrations at the oulet of both the boiler and the ESP
- Particulate collection efficiency
- Particulate size distribution at the boiler outlet and the ESP outlet

Comparisons of these data will show the effects of low NO_x firing on particulate concentration, size distribution, and ease of collection.

Particulate concentration data from both the EPA Method 5 and SASS results are presented in Tables 4-5 and 4-6. The concentrations are reported on a heat input basis (μg/J). In comparing the data from these two tests, recall that the heat input was essentially the same in both tests but the flue gas volumetric flow rate was larger for the baseline case by about 25 percent. The particulate concentrations measured by Method 5 at the boiler outlet in units of mass/volume (g/dscm) only differ by about 2 percent (16.24 g/dscm for LEA versus 15.89 g/dscm for baseline) for both tests. The larger amount of particulate emissions at the boiler outlet for the baseline test is due to the greater gas flow rate rather than changes in particulate concentration loading. At the ESP outlet the particulate loading is 0.027 g/dscm for the LEA test versus 0.018 g/dscm for the baseline test. Because of the larger volumetric flow rate for the baseline test, in units of mass/heat input, the particulate emissions are 20 percent greater at the ESP outlet for the LEA.

To calculate the collection efficiency of the ESP, a collection efficiency must be assumed for the mechanical collector. Based on measurements made by KVB as part of other tests on the same boiler (Reference 2), a collection efficiency of 92 percent is assumed. Based on this assumed collection efficiency and the measured particulate concentration at the boiler and ESP outlet, a value for the ESP collection efficiency was calculated. For the low excess air case, the efficiency was found to be 97.7 percent versus 98.5 percent for the baseline case which is not a significant difference.

Tables 4-7 and 4-8 list particulate size distributions for the two tests. As expected, the average particulate size at the boiler outlet is much larger than at the ESP outlet. The particulate size distribution,

TABLE 4-5. METHOD 5 PARTICULATE CONCENTRATIONS (μg/J)

	Baseline	Low Excess Air
Boiler outlet	7.31	5.82
Mechanical collector outlet[a]	0.58	0.47
ESP outlet	0.008	0.010
ESP collection efficiency[b] (percent)	98.5	97.7

[a] Based on other tests at this site by KVB, the mechanical collector is assumed to be 92 percent efficient (Reference 2).

[b] Calculated assuming 92 percent mechanical collector efficiency with boiler outlet and ESP outlet concentrations being measured.

TABLE 4-6. SASS PARTICULATE CONCENTRATIONS (μg/J)

	Baseline	Low Excess Air
Boiler outlet	9.20	3.76
Mechanical collector outlet[a]	0.74	0.30
ESP outlet	0.002	0.002
ESP collection efficiency[b] (percent)	99.7	99.5

[a] The mechanical collector is assumed to be 92 percent efficient based on other tests at this site by KVB, (Reference 2).

[b] Calculated from measured boiler outlet and ESP outlet values by assuming the mechanical collector is 92 percent efficient

TABLE 4-7. SASS TRAIN PARTICULATE SIZING (CUMULATIVE WEIGHT PERCENT OVERSIZE) BOILER OUTLET

	Baseline	Low Excess Air
10 µm cyclone	81.04	80.25
3 µm cyclone	94.43	94.45
1 µm cyclone	99.20	98.00
Filter	100	100

TABLE 4-8. SASS TRAIN PARTICULATE SIZING (CUMULATIVE WEIGHT PERCENT OVERSIZE) ESP OUTLET

	Baseline	Low Excess Air
10 µm cyclone	6.18	11.19
3 µm cyclone	14.85	12.99
1 µm cyclone	14.85	13.97
Filter	100	100

also appears to be the same for both tests at the boiler outlet. At the ESP outlet most of the particulates are less than 1 μm.

Table 4-9 lists the carbon content of the various ashes. From the data it appears that the larger particles tend to have a larger carbon content. Also LEA firing causes the particles at the boiler outlet to contain more unburned carbon but most of this excess unburned carbon appears to be removed by the mechanical collector as shown by the carbon content of the ESP hopper ash.

TABLE 4-9. CARBON CONTENT OF ASH (percent)

Test	Bottom Ash	Mechanical Collector Hopper Ash	ESP Hopper Ash
LEA	5.03	79.32	22.76
Baseline	--	48.99	22.33

4.4 TRACE ELEMENT CHARACTERIZATION AND EMISSIONS

Samples taken at the various sampling locations shown in Figure 3-1 were analyzed for selected trace elements and ionic species. The samples collected and analyzed were coal, bottom ash, mechanical collector hopper ash, ESP hopper ash, and flue gas at the boiler outlet and the ESP outlet. The flue gas was sampled by using a SASS train. Grab samples from the other streams were collected periodically. The detailed results of these analyses are presented in Appendix C. A bottom ash sample was only collected for the LEA test.

Trace element concentration reported for the XAD-2 and impinger samples have been corrected for blank concentrations. Appendix A describes the atomic adsorption procedures used to analyze samples for selected trace elements. The anion and ammonium concentrations were determined by a neutral extraction of some of the ash samples. The procedure is also outlined in Appendix A.

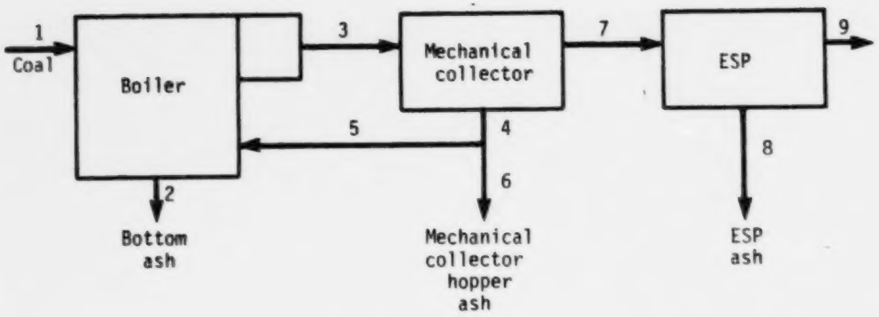
Given the trace element concentrations, trace element flowrates could be determined for each of the streams sampled. To do this an ash material balance was performed. The material balance is shown in Figure 4-3 and was derived via the following procedure. First it is assumed that 50 percent of the ash from the coal becomes bottom ash, as suggested by the manufacturer. It is also assumed that the mechanical collector has the 92 percent efficiency measured by KVB in other tests on this unit (Reference 2). The amount of collected fly ash that is reinjected to the boiler is assumed to be 60 percent. The ash samples (bottom, mechanical hopper, ESP hopper) were analyzed for carbon and hydrogen and the rest of the sample is assumed to be ash. Referring to Figure 4-3, particulate matter in streams 7, 8, and 9 are assumed to have the same ash concentration as the measured ESP hopper ash. Particulate matter in streams 3 and 4 are assumed to have the same carbon and hydrogen concentration as the measured mechanical hopper ash while the ash content of 3 is adjusted so that the amount leaving via stream 9 is consistent with measurements of total particulate emissions from the ESP outlet. These assumptions imply that the larger particles have a larger carbon content. Given all the above assumptions, the material balance should have, at best, an uncertainty of about 20 percent to 30 percent.

One purpose of this study is to measure how the trace elements partition among the various ash streams and if this partition changes with LEA operation. Since the particulate sizes and temperatures vary among the different ash streams, some partitioning might be expected.

Solid Phase Trace Element Concentrations

For the LEA test, trace element flowrates (Appendix D) in the bottom ash were compared to those in the flyash (boiler outlet) to determine if solid phase trace element stream partitioning could be observed. If the flow rates differ by more than a factor of eight or two, partitioning is assumed to have taken place, i.e. if:

$$2\begin{pmatrix}\text{bottom ash element}\\ \text{flowrate}\end{pmatrix} \le \begin{matrix}\text{boiler outlet}\\ \text{element flowrate}\end{matrix} \le 8\begin{pmatrix}\text{bottom ash}\\ \text{element}\\ \text{flowrate}\end{pmatrix}$$


1
Coal
Boiler
2
Bottom ash
3
Mechanical collector
4
5
6
Mechanical collector hopper ash
7
ESP
8
ESP ash
9

Streams	1	2	3	4	5	6	7	8	9	Total ash in / Total ash out
LEA flow rates (kg/min)										
Total (solids only)	143.5	5.64	24.80	22.82	13.69	9.13	1.99	1.94	0.04	0.81
Ash	10.73	5.37	6.16	4.64	2.78	1.85	1.53	1.49	0.03	
Baseline flow rates (kg/min)										
Total (solids only)	145.4	5.24	32.24	29.66	17.80	11.86	2.58	2.54	0.04	1.30
Ash	9.99	4.99	17.06	15.06	9.04	6.02	2.00	1.97	0.03	

Figure 4-3. Ash material balance.

no partitioning is assumed to have taken place. The factors of 8 and 2 are used to correct the flowrates since the boiler outlet ash flowrate is larger than the bottom ash flowrate. If:

$$8\begin{pmatrix}\text{bottom ash element}\\ \text{flowrate}\end{pmatrix} < \begin{array}{c}\text{boiler outlet}\\ \text{element flowrate}\end{array}$$

then flyash partitioning is assumed, and if:

$$2\begin{pmatrix}\text{bottom ash element}\\ \text{flowrate}\end{pmatrix} > \begin{array}{c}\text{boiler outlet}\\ \text{element flowrate}\end{array}$$

then bottom ash partitioning is assumed.

Since the bottom ash was not sampled during the baseline test, partitioning is estimated by comparing the two boiler outlet measurements. If the element flowrates fall within the following limits they are assumed to show the same partitioning trends. If:

$$\begin{array}{c}\text{boiler outlet element}\\ \text{flowrate -- LEA}\end{array} \leq \begin{array}{c}\text{boiler outlet element}\\ \text{flowrate -- baseline}\end{array} \leq 3\begin{pmatrix}\text{boiler out-}\\ \text{let element}\\ \text{flowrate --}\\ \text{LEA}\end{pmatrix}$$

the two tests are assumed to show the same partitioning trends. A factor of 3 is used since the boiler outlet ash flowrate is larger for the baseline test. The results are shown in Table 4-10.

Based on this test, low excess air firing appears to have only a small effect on trace element partitioning between the bottom ash and flyash. Only barium and iron showed any changes in the way in which they partitioned, by the criteria used.

Further flyash stream partitioning can be examined by comparing trace element concentrations in the particulate in the direction of flue gas flow. As the particulate laden flue gas passes through particulate removal devices, trace element stream partitioning may be observed. Particulate collection efficiencies are largely particle size dependent, with the coarser particulate more easily removed. Thus flyash stream partitioning is actually size partitioning.

Trace element concentrations in the mechanical collector hopper flyash and the ESP hopper flyash (Appendix C) were compared. If the concentrations were within a factor of 2, no partitioning was assumed to

TABLE 4-10. SOLIDS TRACE ELEMENT PARTITIONING -- BOTTOM ASH/FLYASH (Boiler Outlet Flyash)

	Baseline[a]	LEA
Antimony	X	FA
Arsenic	FA	FA
Barium	BA	FA
Beryllium	FA	FA
Bismuth	X	X
Boron	FA	X
Cadmium	X	X
Chromium	X	BA
Cobalt	X	X
Copper	FA	BA
Iron	FA	BA
Lead	X	X
Manganese	BA	BA
Mercury	EQ	X
Molybdenum	FA	FA
Nickel	X	X
Selenium	X	FA
Tellurium	X	X
Thallium	X	X
Tin	X	BA
Titanium	BA	BA
Uranium	X	X
Vanadium	BA	BA
Zinc	BA	BA
Zirconium	X	X
Chloride	X	X
Fluoride	FA	FA
Cyanide	X	X
Nitrate	FA	X
Sulfate	FA	FA
Ammonium	X	X

EQ - Material partitioned equally between bottom ash and flyash.
FA - Material preferentially concentrated in flyash.
BA - Material preferentially concentrated in bottom ash.
X - Insufficient data.

[a] Since bottom ash was not measured during the baseline test, the partitioning is based on comparing the two boiler outlet composition for the two tests.

take place. As shown in Table 4-11, except for beryllium, tin, and vanadium, there is no change in trace element partitioning between baseline and LEA operation. For these three elements the partitioning shifted from the ESP hopper flyash toward the mechanical collector flyash as operation was changed from low excess air to baseline. Also the trace elements which tended to collect in ESP flyash over the mechanical collector also tended to collect in the flyash over the bottom ash or distribute equally between the two ashes in most cases. The elements found to favor the flyash over the bottom ash agree with predictions from another reference (Reference 7).

Size Fractionation

Sampling at both the boiler outlet and ESP outlet was conducted using a SASS train as mentioned previously. For the majority of tests, SASS trains were equipped with 10, 3, and 1 micron cyclones followed by a filter. Trace element analyses were conducted on 10 μm, 3 μm samples, 1 μm, and filter samples. A tabulation of the analytical results are shown in Appendix C.

These data were examined to determine if selective trace element partitioning occurs with particle size by comparing 10 μm with 1 μm. Table 4-12 illustrates the presence of this effect at the boiler outlet. Most species concentrations were higher in small particles. Low excess air firing seemed to have little effect on the tendency to partition with particle size. Barium, beryllium, and iron shifted toward smaller particles but the shift was small.

Vapor Phase Trace Element Concentrations

Vapor phase trace element concentrations were obtained from the SASS train samples. The vapor phase species were collected in either the organic module (XAD-2 and condensate) or the impinger portions of the SASS train. In the organic module, flue gas is cooled to approximately 20°C (68°F) and passed through a cross linked porous polymer resin (XAD-2) cartridge. In this section, two samples are generated: the condensate and the XAD-2 sorbent. From the organic module, the flue gas goes through an impinger train containing hydrogen peroxide (one impinger) and silver nitrate-ammonium persulfate (two impingers) solutions. For trace element analysis, the organic module aqueous condensate sample is combined with the hydrogen peroxide impinger sample to form one sample of analysis.

TABLE 4-11. TRACE ELEMENT PARTITIONING -- MECHANICAL COLLECTOR HOPPER FLYASH/ESP HOPPER FLYASH

	Baseline	LEA
Antimony	ESP	ESP
Arsenic	ESP	ESP
Barium	ESP	ESP
Beryllium	EQ	ESP
Bismuth	X	ESP
Boron	MC	X
Cadmium	ESP	ESP
Chromium	MC	MC
Cobalt	MC	X
Copper	MC	MC
Iron	MC	MC
Lead	MC	MC
Manganese	MC	MC
Mercury	X	X
Molybdenum	ESP	ESP
Nickel	MC	MC
Selenium	ESP	ESP
Tellurium	X	X
Thallium	X	X
Tin	MC	EQ
Titanium	MC	MC
Uranium	X	X
Vanadium	MC	EQ
Zinc	MC	MC
Zirconium	X	X
Chloride	X	X
Fluoride	ESP	ESP
Cyanide	X	X
Nitrate	ESP	ESP
Sulfate	ESP	ESP
Ammonium	X	ESP

EQ - Material partitioned equally between mechanical collector hopper flyash and ESP inlet flyash.

MC - Material preferentially concentrated in mechanical collector hopper flyash.

ESP - Material preferentially concentrated in ESP hopper flyash.

X - Insufficient data.

TABLE 4-12. SIZE FRACTIONATION -- BOILER OUTLET

	Baseline	LEA
Antimony	2	2
Arsenic	2	2
Barium	1	0
Beryllium	1	0
Bismuth	2	2
Boron	X	2
Cadmium	2	2
Chromium	X	X
Cobalt	X	X
Copper	0	2
Iron	1	0
Lead	X	X
Manganese	0	0
Mercury	1	X
Molybdenum	0	2
Nickel	X	X
Selenium	2	0
Tellurium	X	X
Thallium	X	X
Tin	X	X
Titanium	X	2
Vanadium	0	0
Zinc	2	2
Chloride	X	X
Fluoride	X	X
Cyanide	X	X
Nitrate	X	X
Sulfate	X	X
Ammonium	X	

0 -- No significant separation
1 -- Concentration enchancement in 10 μm fractions
2 -- Concentration enhancement in the 1 μm fractions
X -- Insufficient data

Thus three vapor phase samples are analyzed: the XAD-2, the aqueous condensate and hydrogen peroxide impinger solution, and the silver nitrate-ammonium persulfate impinger solution.

To determine which trace elements were more concentrated in the vapor phase than in the condensed phase, trace element flowrates (Appendix D) were compared. Using the same stream partitioning criteria as before, trace elements were considered to be concentrated in the vapor phase if their vapor phase flowrates were at least two times their solid phase concentrations. The partitioning results are given in Table 4-13.

Notice that at the boiler outlet most trace elements are found in the solid phase while at the ESP outlet, where the larger particles have been removed, many elements are concentrated in the vapor phase. The vapor phase may also include particles too small to be collected by the filter of the SASS train (<0.3 μm). There were some changes in the partitioning from LEA to baseline condition.

The chromium and nickel values are suspect, however. The aqueous condensate sample is collected in a stainless steel cup in the SASS train organics module. Since the condensate is acidic, chromium and nickel from the stainless steel are likely to appear in the sample. This is probably true for iron also.

Effects Due to NO_x Controls

There were some changes in trace element emissions at the ESP outlet under LEA conditions as compared to baseline condition. There may have been a small decrease in trace element emissions under LEA operation. Barium, copper, iron, vanadium, and zinc all showed decreased concentrations in the flue gas under LEA operation while only cadmium showed a significant increase. The total flue gas flowrate is larger for the baseline case. Therefore there is an indication that the total amount of emitted trace elements is less for the LEA case. Table 4-14 summarizes the overall flue gas compositions at the ESP outlet for the Baseline and LEA tests. The emissions include both vapor phase and solid phase species.

Elemental Mass Balance

A system species mass balance was performed using trace element flow data (Appendix D). Table 4-15 presents the results of the system trace element mass balance. Considering factors affecting the mass balance, the data are within the reliability of the Level 1 sampling and

TABLE 4-13. TRACE ELEMENT PARTITIONING -- SOLID PHASE/VAPOR PHASE

	Baseline		LEA	
	Boiler Outlet	ESP Outlet	Boiler Outlet	ESP Outlet
Antimony	S	X	S	X
Arsenic	S	S	S	S
Barium	S	S	S	V
Beryllium	S	V	S	EQ
Bismuth	S	X	X	X
Boron	X	V	X	V
Cadmium	S	EQ	S	S
Chromium	X	V	V	V
Cobalt	S	S	S	EQ
Copper	S	EQ	EQ	EQ
Iron	V	V	EQ	V
Lead	X	V	V	X
Manganese	S	S	S	S
Mercury	X	V	V	V
Molybdenum	S	V	S	V
Nickel	EQ	V	V	V
Selenium	S	EQ	S	V
Tellurium	X	X	X	V
Thallium	X	X	X	X
Tin	X	EQ	X	X
Titanium	X	V	X	V
Vanadium	S	V	S	V
Zinc	S	V	EQ	V

EQ - Material partitioned equally between vapor and solid phase.
S - Material preferentially concentrated in solid phase.
V - Material preferentially concentrated in vapor phase.
X - Insufficient data.

TABLE 4-14. FLUE GAS COMPOSITIONS AT ESP OUTLET

Test	Baseline	LEA
Heat Input (% of baseline)	100	102
Emissions µg/dscm		
NO_x[a] (ppm @ 3% O_2 dry)	4.7×10^5 (343)	3.4×10^5 (215)
*SO_2 (ppm @ 3% O_2 dry)	5.2×10^5 (272)	3.3×10^5 (149)
*SO_3 (ppm @ 3% O_2 dry)	2.4×10^3 (1)	2.2×10^5 (0.8)
CO (ppm @ 3% O_2 dry)	5.4×10^4 (65)	3.5×10^4 (36)
CO_2 (% dry)	2.1×10^8 (11.6)	2.4×10^8 (13.2)
O_2 (% dry)	(8.1)	(6.0)
Particulate	1.9×10^4	2.9×10^4
Antimony	3.5	3.5
Arsenic	35	39
Barium	170	2.7
Beryllium	1.2	0.25
Bismuth	2.6	3.2
Boron	$<6.8 \times 10^3$	7.8×10^3
Cadmium	<1.2	5.2
Chromium	61	20
Cobalt	23	5.8
Copper	64	0.050
Iron	280	<71.2
Lead	<1.2	<0.5
Manganese	12	11
Mercury	2.4	1.3
Molybdenum	320	210
Nickel	2.6×10^3	2.4×10^3
Selenium	13	13
Tellurium	2.2	<3.0

[a] Reported as µg NO_2/m^3.

*By Shell-Emeryville method, data may be in error.

TABLE 4-14. Concluded

Test	Baseline	LEA
Thallium	2.0	<2.2
Tin	9.5	<8.8
Titanium	<55	<49
Vanadium	130	18
Zinc	9.7	<0.058

TABLE 4-15. TRACE ELEMENT MASS BALANCE -- (OUTLET/INLET)

Test	Baseline	LEA
Antimony	X	X
Arsenic	>16	>9.9
Barium	1.2	0.91
Beryllium	1.4	0.53
Bismuth	X	X
Boron	>20	>24
Cadmium	X	X
Chromium	57	0.66
Cobalt	0.94	0.15
Copper	0.48	0.33
Iron	0.50	0.43
Lead	X	X
Manganese	1.8	3.4
Mercury	0.9	0.3
Molybdenum	X	X
Nickel	4.3	3.2
Selenium	<1.09	1.3
Tellurium	X	X
Thallium	X	X
Tin	31	22
Titanium	0.47	0.39
Vanadium	0.50	0.39
Zinc	0.29	0.17

X -- Insufficient data.

and analysis procedures, which as noted previously, are assumed to be quantitative within a factor of 2 to 3. Arsenic, boron, chromium, tin, and zinc material balances were not within a factor of 3.

4.5 SULFUR SPECIES EMISSIONS

Sulfur species were analyzed in all sample streams according to the following protocol:

- Coal -- sulfur by ultimate analysis
- Bottom ash -- sulfate by titrimetric technique
- Mechanical hopper ash -- sulfate by titrimetric technique
- Flue gas at boiler outlet -- SO_2 and SO_3 by Shell-Emeryville method and sulfate on particulate matter collected in the 10μ cyclone and 3μ cyclone of the SASS train by titrimetric technique.
- Flue gas at ESP outlet -- SO_2 and SO_3 by Shell-Emeryville method

The Shell-Emeryville measurements were performed by KVB and the rest of the analyses by Acurex. Assuming a 50/50 bottom ash to flyash ratio, 92 percent mechanical collector efficiency, and 60 percent of the mechanical collector ash reinjected as explained in Section 4.4, a sulfur balance was performed.

The results of the sulfur species analyses are presented in Table 4-16. The data show that the SO_2/SO_3 ratio is not strongly affected by the changes in firing mode. The data also show that levels of sulfate in the ash sample are higher in the smaller size particulates for both baseline and low excess air firing. This is seen in the progressively higher sulfate level in the direction of flue gas flow and also in the comparison of different size particulate samples collected by the SASS train.

The results of a sulfur balance are shown in Table 4-17. The table shows that the mass balance closure is very poor. This is probably due to the experimental uncertainty in the SO_2 flue gas measurements. The balance does show that most of the sulfur is emitted as SO_2 rather than SO_3 or sulfate.

4.6 ORGANIC ANALYSES

Organic analyses were performed on selected samples according to the EPA Level 1 protocol as outlined in Appendix B (References 4 and 6).

TABLE 4-16. SULFUR SPECIES ANALYSES RESULTS

Test	Baseline	LEA
Heat Input MW	73.3	74.7
Coal - Sulfur %	0.79	0.81
(ng/J)	(260)	(258)
Bottom Ash		
Sulfate μg/g		371
(ng/J)		(0.465)
Mechanical Collector Ash		
Sulfate μg/g	1236.3	848.8
(ng/J)	(3.33)	(1.72)
ESP Hopper Ash		
Sulfate μg/g	11,000	23,000
(ng/J)	(6.35)	(9.93)
Boiler Outlet -- Shell-Emeryville Method		
SO_2 - g/dscm	0.9	0.9
(ng/J)	(390)	(275)
(ppm dry at 3% O_2)	(468)	(391)
SO_3 - mg/dscm	1.7	2.8
(ng/J)	(0.7)	(0.9)
(ppm dry at 3% O_2)	(0.7)	(1.0)
Boiler Outlet -- SASS		
10μ cyclone-sulfate μg/g	1480	1520
3μ cyclone-sulfate μg/g	6350	
ESP Outlet -- Shell-Emeryville		
SO_2 - g/dscm	0.5	0.3
(ng/J)	(227)	(105)
(ppm dry at 3% O_2)	(272)	(149)
SO_3 - mg/dscm	2.4	2.2
(ng/J)	(1.0)	(0.7)
(ppm dry at 3% O_2)	(1.0)	(0.8)

TABLE 4-17. SULFUR BALANCE

Test	Baseline	LEA
Sulfur in coal ng/J	260	258
Sulfur in bottom ash,[a] ng/J	0.15	0.15
Sulfur in mechanical collector hopper ash, ng/J	1.11	0.57
Sulfur in ESP hopper ash, ng/J	2.12	3.31
Sulfur as SO_2/SO_3 at boiler outlet,[b], ng/J	195	138
Sulfur as SO_2/SO_3 at ESP outlet,[b], ng/J	114	53
Recovery at boiler outlet (%)	76	54
Recovery at ESP outlet (%)	45	22

[a] Sulfate was not performed on the bottom ash for the baseline test so it is assumed same as LEA.

[b] Potential errors in SO_2/SO_3 determined by Shell-Emeryville method.

The samples were analyzed as follows: First they were extracted with methylene chloride in a Soxhlet apparatus. The extracts were then subjected to total chromatographable organic (TCO) and gravimetric analyses which determine species with boiling points in the nominal ranges of 373K to 573K and greater than 573K respectively. Infrared spectra were also performed. If certain TCO and gravimetric requirements were met, further analyses by liquid column chromatography, with infrared and mass spectral analyses of the fractions eluted from the column, were performed. In addition, flue gas C_1 to C_6 hydrocarbon compounds were analyzed on site by gas chromatography. The analysis schedule was given in Table 3-2. A discussion of the analytical results follows.

4.6.1 Total Chromatographable Organics (TCO) and Gravimetric Analyses of Organic Extracts

Total chromatographable organics (TCO) and gravimetric analyses were performed on organic extracts of the samples from the Baseline and LEA tests. The samples analyzed were the bottom ash and mechanical collector hopper ash, electrostatic precipitator hopper ash, the samples collected by the SASS trains at the boiler outlet and the ESP outlet, and the XAD-2 sorbent samples collected by the SASS train at the boiler outlet and ESP outlet.

Detailed analysis results are presented in Table 4-18. The results of the analyses indicate that the range of concentrations of organic materials (TCO plus gravimetric) in bottom ash, mechanical collector hopper ash, and ESP hopper ash is 6 to 250 μg/gm. Also notice that the organic content of the ESP hopper shows a higher ratio of TCO organics to gravimetric organics than the other ashes. This means that the ESP ash has a relatively higher portion of the lower boiling organics.

The TCO and gravimetric analyses of the SASS train samples together with the ash samples suggest several conclusions. Since the ESP ash is smaller in size than the ash collected by the mechanical collector, for the LEA test the organics appear to favor the smaller particle sizes as compared to the Baseline test. From the SASS train samples, it appears that the vapor phase organic/solid phase organic ratio is higher for the LEA test as compared to the Baseline test. Also, the vapor phase organic emissions appear to be slightly higher for LEA firing.

TABLE 4-18(a). RESULTS OF GRAVIMETRIC AND TCO ANALYSES OF ASH SAMPLES

Test	Type of Ash	Gravimetric Result (mg)	TCO Result (mg)	Total Organics in Extract (mg)	Wt. of Sample Extracted (g)	Organics in Total Sample µg/g
LEA	Bottom	28.4	2.2	30.6	254.2	120.4
Baseline	Mechanical hopper	1.3	<0.1	1.3	21.34	61
LEA	Mechanical hopper	0.1	<0.1	0.1	16.88	6
Baseline	ESP hopper	0.6	0.2	0.8	10.95	73.0
LEA	ESP hopper	1.4	0.9	2.3	8.967	256.5

TABLE 4-18(b). RESULTS OF GRAVIMETRIC AND TCO ANALYSES OF SASS SAMPLES

Test	Type of Sample	Gravimetric Result (mg)	TCO Result (mg)	Total Organics in Extract (mg)	Wt. of Sample Extracted (g)	Organics in Total Sample	
						μg/g	μg/dscm
Baseline	Boiler outlet- 10μ + 3μ flyash	1.8	0.1	1.9	13.39	142	2850
LEA	Boiler outlet- 10μ + 3μ flyash	<0.1	<0.1	<0.2	7.24	<28	<314
LEA	Boiler outlet- XAD-2 and organic condensate	54.7	<0.1	54.7	--	--	6300
Baseline	ESP outlet- XAD-2 and condensate	23.5	1.8	25.3	--	--	924
LEA	ESP outlet- XAD-2 and condensate	34.5	3.0	37.5	--	--	1370

Volume of gas sampled (dscm)

Baseline Boiler outlet: 12.9   LEA Boiler outlet: 8.7

ESP outlet: 27.4   ESP outlet: 27.4

To qualify for liquid column separation, a sample was required to contain at least 15 mg organic material. Four samples (LEA-Bottom Ash, LEA-Boiler outlet XAD-2, LEA-ESP outlet XAD-2, Baseline-ESP outlet XAD-2) met this criterion. These samples were separated for further analysis.

4.6.2 Infrared Spectra of Total Extracts

The materials used in the gravimetric analyses were prepared for infrared spectra determination. The summary of the IR analyses of these total extracts are given in Table 4-19. Appendix E lists the IR Spectrum. Analytical procedures are discussed in Appendix B. The IR results, while similar for the two tests, were not exactly the same. This is an indication that the kinds of organic species produced by the two tests were slightly different. The IR of the ESP hopper and ash extract indicated an ester for the low excess air test while for the baseline test an ether was indicated. For both tests, the ESP outlet showed indications of aliphatic hydrocarbons, esters, and carboxylic acids. The ash hoppers showed these same classes of compounds also.

4.6.3 Column Chromatography

The extracts from the four samples described above were concentrated and fractionated via liquid chromatography according to Level 1 procedures (References 4 and 6). Gravimetric and total chromatographable organic content for each fraction were then obtained. These data are given in Tables 4-20, 4-21, 4-22, and 4-23.

4.6.4 Infrared and Mass Spectral (LRMS and GC/MS) Analyses of Fractions from Column Chromatography

The samples obtained from the liquid chromatography fractionations were split and subjected to infrared spectroscopy. In addition to infrared analyses, the liquid fractions two and three from the LEA-bottom ash sample were analyzed by GC/MS (gas chromatograph-mass spectrometer). The following liquid chromatograph (LC) fractions were also analyzed by low resolution mass spectroscopy (LRMS):

1) LEA-ESP outlet-XAD-2 - LC fraction 6
2) Baseline - ESP outlet-XAD-2 - LC fraction 7
3) LEA - bottom ash - all LC fractions
4) Blank - XAD extract - LC fractions 6 and 7.

The infrared spectrum from the LC fractions are listed in Appendix E. Table 4-24 lists a summary of the IR's of the LC fractions.

TABLE 4-19. INFRARED SPECTRUM SUMMARY

Spectrum Source	Principal Constituents	
	Low NO_x	Baseline
Bottom ash extract	Aliphatic hydrocarbons, aromatic/aliphatic ester,* aliphatic carboxylic acid	Sample not available
XAD-2 resin boiler outlet SASS	Aromatic/aliphatic ester,* aromatic and aliphatic carboxylic acid	Carboxylic acid, alcohol, possible ester
Flyash extract (10μ + 3μ) boiler outlet SASS	Weak spectrum, carbonyl present	Aliphatic hydrocarbons, weak spectrum
Mechanical hopper ash extract	Aliphatic hydrocarbons	Aliphatic hydrocarbons, weak spectrum
ESP hopper ash extract	Possible ester present	Spectrum possibly of carboxylic acid
XAD-2 resin ESP outlet SASS	Aliphatic hydrocarbon,* ether, carboxylic acid	Aliphatic hydrocarbon,* ester, carboxylic acid

*Sample subsequently chromatographed IR's taken of all fractions.

TABLE 4-20. GRAVIMETRIC AND TCO RESULTS FROM LIQUID CHROMATOGRAPHY OF LEA-BOTTOM ASH

Fraction	TCO (mg)	Gravimetric (mg)	Total (mg)	Organic in Total Sample (¨g/g)
1	4.3	4.0	8.3	32.6
2	0.5	0.3	0.8	3.1
3	1.4	7.5	8.9	35.0
4	0.3	3.4	3.7	14.6
5	0.3	2.2	2.5	9.8
6	0.2	1.6	1.8	7.1
7	0.2	7.7	7.9	31.1
Total	7.2	26.7	33.9	133.3

TABLE 4-21. GRAVIMETRIC AND TCO RESULTS FROM LIQUID CHROMATOGRAPHY OF LEA-BOILER OUTLET-XAD-2

Fraction	TCO (mg)	Gravimetric (mg)	Total (mg)	Organic in Total Sample (mg/dscm)
1	0.6	0.2	0.8	0.1
2	< 0.1	0.3	0.3	0.03
3	< 0.1	0.2	0.2	0.02
4	< 0.1	< 0.1	< 0.2	< 0.02
5	0.1	0.3	0.4	0.05
6	< 0.1	2.0	2.0	0.2
7	0.2	9.2	9.4	1.1
Total	0.9	12.2	13.1	1.5

TABLE 4-22. GRAVIMETRIC AND TCO RESULTS FROM LIQUID CHROMATOGRAPHY OF LEA-ESP OUTLET-XAD-2

Fraction	TCO (mg)	Gravimetric (mg)	Total (mg)	Organic in Total Sample (mg/dscm)
1	0.1	1.9	2.0	0.07
2	< 0.1	< 0.1	< 0.2	< 0.01
3	1.1	2.6	3.7	0.14
4	0.3	0.3	0.6	0.02
5	0.4	0.1	0.4	0.01
6	0.1	18.0	18.1	0.66
7	< 0.1	1.6	1.6	0.06
Total	2.0	24.4	26.4	0.96

TABLE 4-23. GRAVIMETRIC AND TCO RESULTS FROM LIQUID CHROMATOGRAPHY OF BASELINE-ESP OUTLET-XAD-2

Fraction	TCO (mg)	Gravimetric (mg)	Total (mg)	Organic in Total Sample (mg/dscm)
1	< 0.1	0.6	0.6	0.02
2	< 0.1	0.4	0.4	0.01
3	0.4	0.3	0.7	0.02
4	< 0.1	0.3	0.3	0.01
5	0.7	0.9	1.6	0.06
6	1.9	3.1	5.0	0.18
7	0.9	18.4	19.3	0.70
Total	3.9	24.0	27.9	1.02

TABLE 4-24. SUMMARY OF IR's OF LC FRACTIONS

Sample	Compounds Found
Bottom ash, LEA	
all fractions	aliphatic hydrocarbons
LC fraction 3	aromatic
LC fraction 7	carboxylic acid, ester
XAD-2 extracts, boiler outlet, LEA	
all fractions	aliphatic compounds
LC fraction 4	aromatic compounds ester
LC fraction 5	aromatic compounds
LC fraction 6	aromatic compounds carboxylic acid
LC fraction 7	aromatic compound carboxylic acid
XAD-2 extracts, ESP outlet, LEA	
all fractions	aliphatic compounds
LC fraction 3	ether
LC fraction 4	aromatic compounds, ether
LC fraction 5	aromatic compounds ester
LC fraction 6	aromatic compound carboxylic acid, ester
LC fraction 7	carboxylic acid, ester
XAD-2 extracts, ESP outlet, Baseline	
all fractions	aliphatic compounds
LC fraction 4	aromatic compounds
LC fraction 5	aromatic compounds, ester
LC fraction 6	aromatic compounds, ester, carboxylic acid
LC fraction 7	aromatic, ester

For the ESP outlet, both tests, LEA and baseline, showed the same type of compounds except for an ether in the LEA test that was not found in the baseline test. The IR of the total XAD-2 extract had also showed the presence of an ether compound. The results from the GC/MS analysis of the bottom ash extracts are listed in Table 4-25. Table 4-26 lists the compounds looked for by GC/MS. Phenanthrene/anthracene, fluoranthene, and pyrene were found. The LRMS of the various samples did not yield any additional information.

4.6.5 C_1 to C_6 Hydrocarbon Analysis of Flue Gas

Onsite analysis of C_1 to C_6 hydrocarbons in the flue gas were conducted via gas grab samples and a gas chromatograph with a flame ionization detector. The samples were collected at the ESP outlet and the results are presented in Table 4-27. Emissions of these lower boiling organics were higher for the LEA test.

4.6.6 Summary of Organic Emissions

There appears to be no major change in the types of organics emitted from the ESP during low NO_x operation. The XAD-2 resin extracts from the ESP outlet SASS train for the LEA tests did show an apparent cyclic symmetrical ether which was not found in any other extracts.

4.7 BIOASSAYS

Bioassays were conducted on bottom ash and ESP ash samples from the low excess air test. The test and results are summarized in Table 4-28 with a more complete summary presented in the appendix. Of all the tests conducted, only the rabbit alveolar macrophage (RAM) test on the ESP hopper ash showed any toxicity at all. This test showed low toxicity. Thus it can be concluded that the bottom ash and ESP ash produced by the LEA test conditions has very low toxicity.

TABLE 4-25. GCMS RESULTS ON LEA BOTTOM ASH EXTRACT (LC fractions 2 & 3)

Compound	Retention Time (min)	m/e Values	Concentration[a] (μg/g)
Alkanes	16-30	57, 71	15
Phenanthrene/ anthracene	20	178	0.6
Fluoranthene	23	202	0.015
Pyrene	24	202	0.03

[a] Based on 254.2 grams extracted.

TABLE 4-26. POLYNUCLEAR AROMATIC HYDROCARBONS SOUGHT IN BOTTOM ASH EXTRACT

Compound	m/e Value
7,12 dimethyl benz (a) anthracene	256
Dibenz (a,h) anthracene	278
Benzo (c) phenanthrene	228
3-methyl cholanthrene	268
Benzo (a) pyrene	252
Dibenzo (a,h) pyrene	302
Dibenzo (a,i) pyrene	302
Dibenzo (c,g) carbazole	267
Fluoranthene	202
Pyrene	202
Anthanthrene	276
Benz (a) anthracene	228
Benzo (g,h,i) perylene	276
Benzo (e) pyrene	252
Anthracene/phenanthrene	178
Perylene	276

TABLE 4-27. C_1 TO C_6 HYDROCARBON ANALYSIS OF ESP OUTLET

Test	Component	Concentration ppm
LEA	Methane	20.9
	Unknown	13.8
	Unknown	68.1
Baseline	Methane	22.9

TABLE 4-28. BIOASSAY RESULTS OF LEA ASH[a]

Ash	Test[b]				
	Ames	RAM	Rat	Freshwater Algal	Freshwater Fish
Bottom	Negative ND	ND EC50 > 1g/ℓ	ND LD50 > 10g/kg	Negative ND	ND LC50 > 1g/ℓ
ESP	Negative ND	L EC50 ≥ 330 mg/ℓ	ND LD50 > 10g/kg	--	--

[a] ND = Not detectable toxicity
L = Low toxicity
LD50 = Dose lethal to 50% of test population
LC50 = Concentration lethal to 50% of test population
EC50 = Concentration gives toxic response in 50% of test population

[b] RAM = Rabbit Alveolar Macrophage toxicity assay
RAT = Whole animal Rodent Acute toxicity assay

SECTION 5
SUMMARY

The test program conducted on this industrial boiler investigated changes in unit operation and multimedia emissions resulting from NO_x control implementation. The results of a baseline or normal operation test were compared to test results from a test of low NO_x operation. This low NO_x operation, low excess air, achieved 43 percent reduction in NO_x from the baseline level. This compares favorably with typical NO_x reductions of 10 to 25 percent while using low excess air. Summaries of the effects on boiler operation and emissions are given below.

Operation

The combustion modification NO_x controls employed in this test program did not appear to cause any operating problems during the test program. Steam temperatures and pressures were maintained at 533 K (500^oF) and 1.4 MPa (190 psig). It must be noted, however, that these tests lasted five to six hours each. The long term effects of continuous operation under low NO_x firing modes were not evaluated in this program.

The combustion modifications consisted of reducing the overall excess air level. In doing this, more operator vigilance is required. If excess air levels are reduced too much, excursions in carbon monoxide concentrations can result. This would represent poor fuel utilization and could also lead to serious problems if explosive CO concentrations are reached.

Boiler efficiency improved slightly with NO_x controls. The efficiency increase is attributable to the effect lowering excess air has upon the amount of flue gas and the level of unburned carbon in the ash.

Emissions

Multimedia emissions were examined for changes due to NO_x controls. Gaseous, particulate, trace element, sulfur species, and organic emissions were evaluated. The test program results are discussed briefly in the following paragraphs.

Gaseous NO_x and CO were measured by continuous monitors during the tests. The NO_x control methods used resulted in 43 percent reduction in NO_x from baseline levels. CO levels were held at levels below 65 ppm throughout the test program. That is, excess air levels were reduced until increases in CO emissions were seen. The excess air level was then increased slightly to provide a comfortable operating margin. Thus, changes in CO levels resulting from NO_x controls were not a problem.

Particulate testing showed that LEA firing resulted in only slightly greater particulate emissions. ESP collection efficiency may have been slightly better under baseline conditions as compared to LEA conditions.

Trace element and leachable ionic specie tests showed only slight differences in partitioning between low NO_x and baseline operation. It appears that most of the trace elements emitted from the ESP outlet are either in the vapor phase or emitted as very small particles. This was found for both modes of operation.

The results of the sulfur species analyses showed that the SO_3/SO_2 ratio is not strongly affected by the changes in firing modes. Sulfate concentrations were higher in the smaller particulate regardless of firing mode.

The organic emissions from the baseline and LEA test were compared. Vapor phase organic emissions may be 15 percent higher for LEA operation. This difference may be due to experimental error. There was only a slight difference seen in the type of organics emitted between the modes of operation.

Bioassay tests conducted on the bottom ash and ESP ash from LEA firing showed low or nondetectable toxicity levels. Only one test showed any negative response.

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APPENDIX A

OPERATING DATA AND EFFICIENCY TEST RESULTS

TEST 2 - BASELINE

DATE 2-7-78

TIME

AVERAGES

5

Drum Level red/green (gage glass)	4/3
Drum Pres. PSIG (gage)	211
Steam Flow MLB/hr (gage)	180
Drum Level in.± (control)	0.0
Feedwater %	73 %
Furnace Pres. in H_2O	-0.28
FD FAN Damper %	95 %
Air Flow %	88 %
Steam/Air Ratio %	74 %
Overfire Air Value %	56 %
Boiler Submaster %	84 %
Plant Master PSIG	182
Overfire Air Pres. in. H_2O (gage)	
Front - upper	8
lower	5.2
Rear - upper	29
lower	31
BLR Hopper Reinj. Pres. in H_2O (gage)	6
Mech. Hopper Reinj. Pres. in H_2O (gage)	11
Grate Speed Setting 0-10 left/rt.	4.9/5.2

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AVERAGES

EST	2
DATE	2-7-78
TIME	
Overfire Air Pres. in H_2O (GAGE)	32
FDFAN Discharge Pres. in H_2O	2.6
Furnace Pres. in H_2O	− 0.2
Grate Draft in H_2O	+ 0.3
Boiler Outlet Pres. in H_2O	− 1.6
Economizer Inlet Pres. in H_2O	5.6
Precipitator Inlet Pres. in H_2O	-8.4
Precipitator Outlet Pres. in H_2O	-8.7
FD FAN AMPS (meter)	78
Overfire Air Fan AMPS	113
ID FAN AMPS	112
Drum Pres. PSIG (chart)	209
Feedwater Pres. PSIG	275
Steam Header Pres. PSIG	187
Feedwater Flow MLB/hr (chart)	183
Steam Flow MLB/hr	182
Air Flow %	85
Econ. Outlet Gas Temp °F (chart)	409
Steam Temp. °F	563
Econ. Inlet Water Temp. °F	244
Econ. Outlet Water Temp. °F	277

TEST 2
DATE 2-7-78
TIME

AVERAGES

Wet Bulb Temp. °F		
Dry Bulb temp. °F		
Coal Scale "A" Counter x 200 lb	462356	462556
Coal Scale "B" Counter x 200 lb	442141	442341
Feedwater Flow Integrator x 1000 lb	732179	732946
Steam Flow Integrator x 1000 lb	618444	619183
Blowdown %	8 %	

TEST #1 LEA

VERAGES

DATE 2-6-78

TIME

Overfire Air Pres. in H_2O (GAGE)	27
FDFAN Discharge Pres. in H_2O	1.3
Furnace Pres. in H_2O	-0.2
Grate Draft in H_2O	0.2
Boiler Outlet Pres. in H_2O	-1.1
Economizer Inlet Pres. in H_2O	-3.7
Precipitator Inlet Pres. in H_2O	-5.4
Precipitator Outlet Pres. in H_2O	-5.5
FD FAN AMPS (meter)	70
Overfire Air Fan AMPS	112
ID FAN AMPS	97
Drum Pres. PSIG (chart)	210
Feedwater Pres. PSIG	275
Steam Header Pres. PSIG	190
Feedwater Flow MLB/hr (chart)	180
Steam Flow MLB/hr	183
Air Flow %	64
Econ. Outlet Gas Temp °F (chart)	396
Steam Temp. °F	561
Econ. Inlet Water Temp. °F	247
Econ. Outlet Water Temp. °F	269

TEST 1
DATE 2-6-78
TIME

AVERAGES

Drum Level red/green (gage glass)	3/4
Drum Pres. PSIG (gage)	~~210~~ 207
Steam Flow MLB/hr (gage)	180
Drum Level in.± (control)	+ 0.5
Feedwater %	% 73
Furnace Pres. in H_2O	- 0.3
FD FAN Damper %	74 %
Air Flow %	65 %
Steam/Air Ratio %	74 %
Overfire Air Value %	46 %
Boiler Submaster %	88 %
Plant Master PSIG	181
Overfire Air Pres. in. H_2O (gage)	
Front - upper	8
lower	5.5
Rear - upper	25
lower	28
BLR Hopper Reinj. Pres. in H_2O (gage)	6
Mech. Hopper Reinj. Pres. in H_2O (gage)	5
Grate Speed Setting 0-10 left/rt.	5.7/6.1

EST 1

DATE 2-6-78

TIME

VERAGES

Wet Bulb Temp. °F		
Dry Bulb temp. °F		
Coal Scale "A" Counter x 200 lb	441367	441562
Coal Scale "B" Counter x 200 lb	461559	461765
Feedwater Flow Integrator x 1000 lb	729203	729973
Steam Flow Integrator x 1000 lb	615608	616348
Blowdown %	8	

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

TEST NO 1	BOILER NO.	DATE 2/6/78
OWNER OF PLANT	LOCATION	
TEST CONDUCTED BY	OBJECTIVE OF TEST LEA	DURATION
ER MAKE & TYPE	RATED CAPACITY	
STOKER TYPE & SIZE		
PULVERIZER, TYPE & SIZE	BURNER, TYPE & SIZE	
FUEL USED	MINE	COUNTY
STATE	SIZE AS FIRED	

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	225
2	STEAM PRESSURE AT S. H. OUTLET	psia	216
3	STEAM PRESSURE AT R. H. INLET	psia	
4	STEAM PRESSURE AT R. H. OUTLET	psia	
5	STEAM TEMPERATURE AT S. H. OUTLET	F	561
6	STEAM TEMPERATURE AT R H INLET	F	
7	STEAM TEMPERATURE AT R.H. OUTLET	F	
8	WATER TEMP. ENTERING [✓ (ECON.)] (BOILER)	F	247
9	STEAM QUALITY % MOISTURE OR P.P.M.		
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	47
12	TEMPERATURE OF FUEL	F	
13	GAS TEMP. LEAVING (Boiler) [✓ (Econ.)] (Air Htr.)	F	396
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	360
1	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb	1301
17	ENTHALPY OF SAT. FEED TO (BOILER) [✓ (ECON.)]	Btu/lb	215
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	—
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	—
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1086
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	—
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	0.117
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	6714
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.697
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	11.32

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	
27	REHEAT STEAM FLOW	lb/hr	
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	18942
29	TOTAL HEAT INPUT $\frac{\text{(Item 28 × Item 41)}}{1000}$	kB/hr	255376
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	
31	TOTAL HEAT OUTPUT $\frac{\text{(Item 26 × Item 20) + (Item 27 × Item 21) + Item 30}}{1000}$	kB/hr	

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	15.8
	O_2	% VOL	3.2
34	CO	% VOL	0.003
35	N_2 (BY DIFFERENCE)	% VOL	81.0
36	EXCESS AIR	%	17.3

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	2.54	51	FLASH POINT F*	
38	VOL MATTER	7.48	52	Sp. Gravity Deg. API*	
39	FIXED CARBON	53.48	53	VISCOSITY AT SSU* BURNER SSF	
40	ASH	7.48	44	TOTAL HYDROGEN % wt	
	TOTAL		41	Btu per lb	
41	Btu per lb AS FIRED	13482			
42	ASH SOFT TEMP.* ASTM METHOD			GAS	% VOL

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS				
			54	CO	
43	CARBON	75.11	55	CH_4 METHANE	
44	HYDROGEN	4.97	56	C_2H_2 ACETYLENE	
45	OXYGEN	7.64	57	C_2H_4 ETHYLENE	
46	NITROGEN	1.38	58	C_2H_6 ETHANE	
47	SULPHUR	0.81	59	H_2S	
40	ASH	7.48	60	CO_2	
37	MOISTURE	2.54	61	H_2 HYDROGEN	
	TOTAL			TOTAL	

	COAL PULVERIZATION				
				TOTAL HYDROGEN % wt	
48	GRINDABILITY INDEX*		62	DENSITY 68 F ATM. PRESS.	
49	FINENESS % THRU 50 M*		63	Btu PER CU FT	
50	FINENESS % THRU 200 M*		41	Btu PER LB	
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	$\frac{\text{ITEM 31} \times 100}{\text{ITEM 29}}$			

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	948	7.03
66	HEAT LOSS DUE TO MOISTURE IN FUEL	31	0.23
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	444	3.29
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	785	5.83
69	HEAT LOSS DUE TO RADIATION		0.50
70	UNMEASURED LOSSES		1.5
71	TOTAL		18.38
72	EFFICIENCY = (100 – Item 71)		81.62

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a(19

TEST NO 2 BOILER NO. DATE 2/7/78
OWNER OF PLANT
LOCATION
TEST CONDUCTED BY
OBJECTIVE OF TEST BASELINE DURATION
ER MAKE & TYPE
STOKER TYPE & SIZE RATED CAPACITY
PULVERIZER, TYPE & SIZE
BURNER, T & SIZE
FUEL USED MINE COUNTY STATE SIZE AS FIRED

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	224
2	STEAM PRESSURE AT S. H. OUTLET	psia	202
3	STEAM PRESSURE AT R. H. INLET	psia	—
4	STEAM PRESSURE AT R. H. OUTLET	psia	—
5	STEAM TEMPERATURE AT S. H. OUTLET	F	563
6	STEAM TEMPERATURE AT R H INLET	F	—
7	STEAM TEMPERATURE AT R.H. OUTLET	F	—
8	WATER TEMP. ENTERING (ECON.)(BOILER)	F	244
9	STEAM QUALITY % MOISTURE OR P. P. M.		
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	48
12	TEMPERATURE OF FUEL	F	
13	GAS TEMP. LEAVING (Boiler)/[✓ (Econ.)] (Air Htr.)	F	408
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	356
1	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb	1303
17	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb	212
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb	—
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	—
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1091
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	—
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	0.135
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	4762
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.686
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	14.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	
27	REHEAT STEAM FLOW	lb/hr	
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	19200
29	TOTAL HEAT INPUT $\frac{\text{Item 28} \times \text{Item 41}}{1000}$	kB/hr	250502
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	
31	TOTAL HEAT OUTPUT $\frac{(\text{Item 26} \times \text{Item 20}) + (\text{Item 27} \times \text{Item 21}) + \text{Item 30}}{1000}$	kB/hr	

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.2
	O_2	% VOL	6.9
34	CO	% VOL	0.005
35	N_2 (BY DIFFERENCE)	% VOL	80.9
36	EXCESS AIR	%	46.6

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	5.66
38	VOL MATTER	35.17
39	FIXED CARBON	52.30
40	ASH	6.87
	TOTAL	
41	Btu per lb AS FIRED	13047
42	ASH SOFT TEMP.* ASTM METHOD	

	OIL	
51	FLASH POINT F*	
52	Sp. Gravity Deg. API*	
53	VISCOSITY AT SSU* BURNER SSF	
44	TOTAL HYDROGEN % wt	
41	Btu per lb	

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	73.03
44	HYDROGEN	4.90
45	OXYGEN	7.32
46	NITROGEN	1.36
47	SULPHUR	0.79
40	ASH	6.87
37	MOISTURE	5.66
	TOTAL	

	GAS	% VOL
54	CO	
55	CH_4 METHANE	
56	C_2H_2 ACETYLENE	
57	C_2H_4 ETHYLENE	
58	C_2H_6 ETHANE	
59	H_2S	
60	CO_2	
61	H_2 HYDROGEN	
	TOTAL	
	TOTAL HYDROGEN % wt	
62	DENSITY 68 F ATM. PRESS.	
63	Btu PER CU FT	
41	Btu PER LB	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	
49	FINENESS % THRU 50 M*	
50	FINENESS % THRU 200 M*	

64 INPUT-OUTPUT EFFICIENCY OF UNIT % $\frac{\text{ITEM 31} \times 100}{\text{ITEM 29}}$

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1227	9.40
66	HEAT LOSS DUE TO MOISTURE IN FUEL	56	0.43
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	440	3.37
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	642	4.93
69	HEAT LOSS DUE TO RADIATION		0.50
70	UNMEASURED LOSSES		1.50
71	TOTAL		20.13
72	EFFICIENCY = (100 – Item 71)		79.87

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

APPENDIX B

ANALYTICAL PROCEDURE

Level 1 Organic Analysis Procedure Modification

Pilot Studies Protocol

Reasons for this Modification:

The original Level 1 Organic Analysis Procedure, as specified in the June 1976 Procedures Manual, was designed in a manner which provided qualititative compound class identification and quantitative (gravimetric) data for those components of a sample that are retained when an organic sample extract is evaporated to dryness. For more volatile sample components, only quantitative information (quantities of material in defined boiling point ranges) was to be obtained. It was implicitly assumed that all compounds with boiling points $\geq$ca. 220°C (C_{13} and higher normal hydrocarbon range) would be retained and carried through the LC-IR-LRMS procedure, while those boiling below 220°C (C_{12} and lower normal hydrocarbons down to C_7*) might be lost during sample evaporation to dryness.

New experimental data have shown that:

1. The range of material lost when the sample is evaporated to dryness for the gravimetric analysis and preparation of the LC sample is somewhat higher than anticipated: It is probably only C_{16} and higher (rather than C_{13} and higher) hydrocarbons that are retained. The C_{16} n-alkane boiling point is about 275°C.
2. Many of the compounds which are considered to be of concern in environmental assessment as a whole (not just Level 1) are in the boiling point range that would correspond to loss prior to LC,

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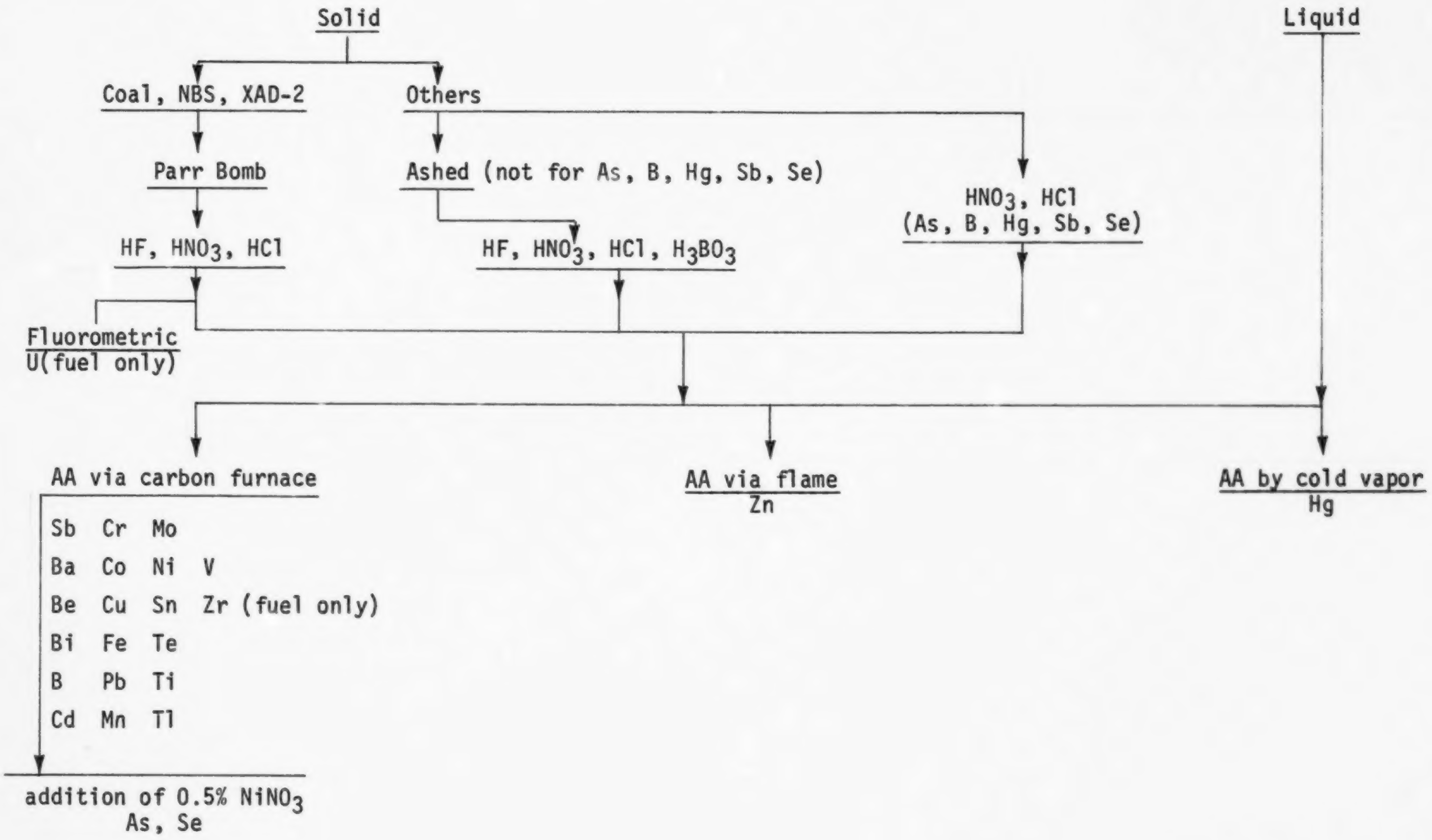
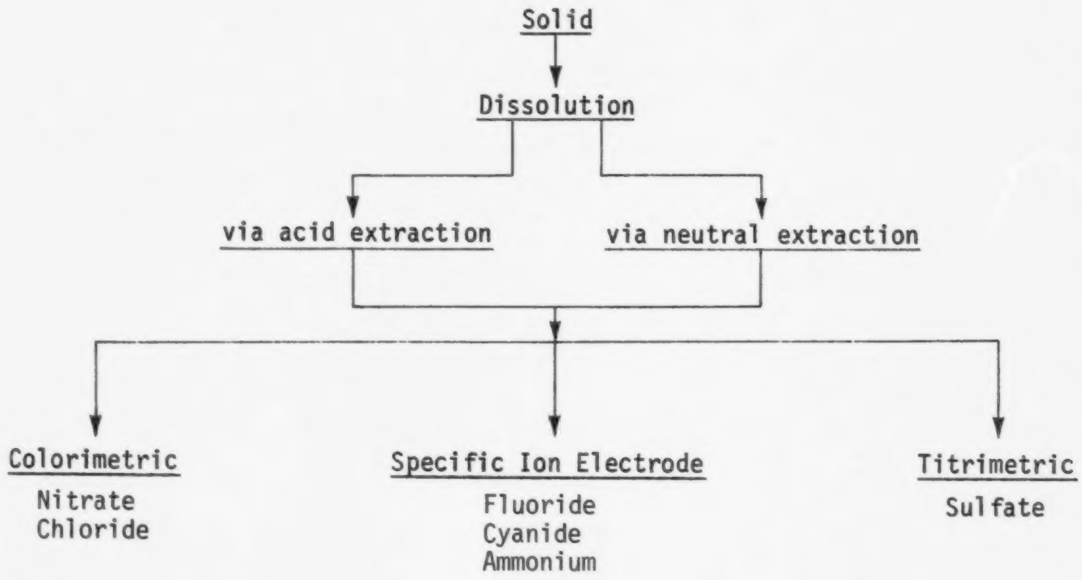
*C_1-C_6 are to be done on-site GC.

ELEMENTAL ANALYSIS FLOW SHEET


Solid
Liquid
Coal, NBS, XAD-2
Others
Parr Bomb
Ashed (not for As, B, Hg, Sb, Se)
HNO_3, HCl
(As, B, Hg, Sb, Se)
HF, HNO_3, HCl
HF, HNO_3, HCl, H_3BO_3
Fluorometric
U(fuel only)
AA via carbon furnace
AA via flame
Zn
AA by cold vapor
Hg
Sb Cr Mo
Ba Co Ni V
Be Cu Sn Zr (fuel only)
Bi Fe Te
B Pb Ti
Cd Mn Tl
addition of 0.5% $NiNO_3$
As, Se

ANIONS PLUS AMMONIUM ANALYSIS FLOW SHEET


Solid
Dissolution
via acid extraction
via neutral extraction
Colorimetric
Nitrate
Chloride
Specific Ion Electrode
Fluoride
Cyanide
Ammonium
Titrimetric
Sulfate

according to present procedures. Thus, no compound class information would be available from Level 1 to indicate the possible presence or to confirm the absence of significant amounts of these materials.

A revised procedure for Level 1 has been devised and subjected to limited experimental validation. The principal feature of this procedure, compared to the original, is that the organic extract is not evaporated to dryness prior to LC and/or LRMS analyses. Two new sample handling steps are required:

- A quantitative assay procedure, TCO (total chromatographable organics) to complement the gravimetric analysis, and give quantitative data on C_7-C_{16} range materials.
- A solvent exchange step to transfer the sample from CH_2Cl_2 extract to a non-polar solvent and allow lower boiling material (>C7) to go through LC and subsequent steps.

A new flow diagram is shown in Figure 1. The two new procedures are described on the following pages.

The total mass data for extracted samples is now taken as the sum of the value determined from the TCO and gravimetric assay. (TCO + GRAV)

Note that the C7 - C12 GC assay is now not required.

Both qualitative and quantitative data are expected to be obtained by this scheme for all materials boiling above the C_7 paraffin.

All other provisions, criteria and instruction of the Procedures Manual apply except for the noted changes.

TCO

Analyze a 1 $\mu\ell$ aliquot of solution by GC using a flame ionization detector. A 6 ft x 1/8 in. O.D. column of 10 percent OV-101 on 100/120 mesh Supelcoport has been used successfully for this analysis. Other silicon phases (OV-1, etc.) may work as well, but a 10 percent loading is recommended. The GC should be operated isothermally at about 30°C - or room temperature - for 5 minutes after sample injection and then programmed at approximately 20°C per minute to 250°C and held at 250°C as long as necessary for complete elution of sample.

Integrator should be set to begin integration at heptane (C_7) peak maxima and terminate at the peak maxima of the heptadecane (C_{17}) peak, as determined from calibration standards. In this manner the integrated area will cover material in the boiling range of C_7-C_{16}.

Calibration should be done with a mixture containing a homologous series of hydrocarbons from C_7 to C_{16}. Standards should be prepared to cover the concentration range to be studied.

Solvent Exchange:

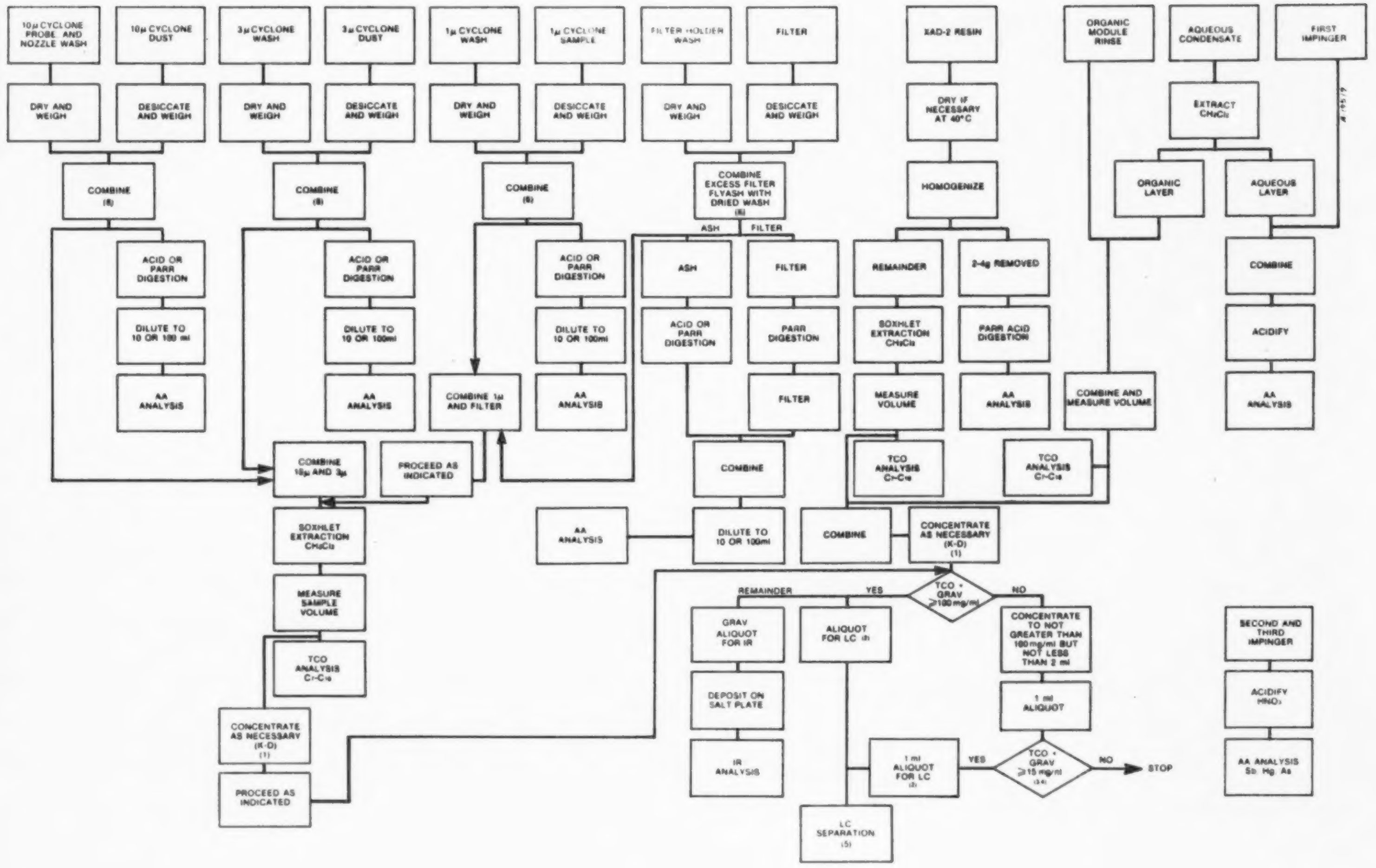
Place 1-5 mℓ of CH_2Cl_2 extract containing 15-100 mg of solute (TCO + GRAV), preferably 100 mg, in graduated centrifuge tube or K-D receiver. Add 200 mg of silica gel prepared as for the LC column. Evaporate if necessary to reduce volume to 1 mℓ.

Add 1 mℓ cyclopentane and mix by gentle agitation. Again reduce volume to 1 mℓ by evaporation.

Add 1 mℓ more of cyclopentane and mix. Reduce volume to 1 mℓ again.

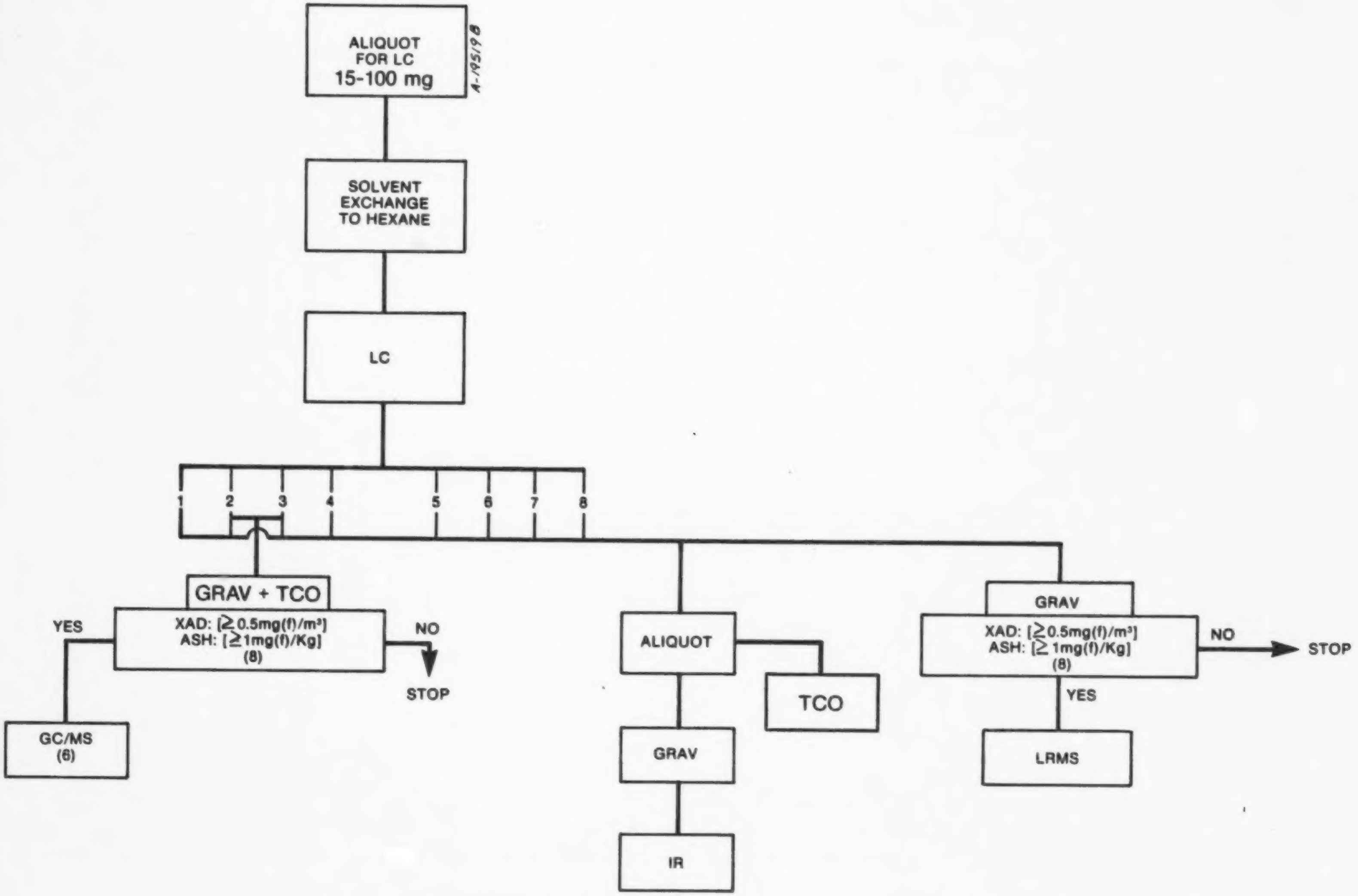
Transfer cyclopentane and silica gel (a Pasteur pipette works well) to top of previously prepared LC column.

Run column as directed in Manual, rinsing graduated receiver with fresh solvents as they are introduced in the elution sequence.


10μ CYCLONE PROBE AND NOZZLE WASH
10μ CYCLONE DUST
3μ CYCLONE WASH
3μ CYCLONE DUST
1μ CYCLONE WASH
1μ CYCLONE SAMPLE
FILTER HOLDER WASH
FILTER
XAD-2 RESIN
ORGANIC MODULE RINSE
AQUEOUS CONDENSATE
FIRST IMPINGER
DRY AND WEIGH
DESICCATE AND WEIGH
DRY AND WEIGH
DESICCATE AND WEIGH
DRY AND WEIGH
DESICCATE AND WEIGH
DRY AND WEIGH
DESICCATE AND WEIGH
DRY IF NECESSARY AT 40°C
EXTRACT CH2Cl2
COMBINE (8)
COMBINE (8)
COMBINE (6)
COMBINE EXCESS FILTER FLYASH WITH DRIED WASH (6)
HOMOGENIZE
ORGANIC LAYER
AQUEOUS LAYER
ASH
FILTER
ACID OR PARR DIGESTION
DILUTE TO 10 OR 100 ml
AA ANALYSIS
ACID OR PARR DIGESTION
DILUTE TO 10 OR 100ml
AA ANALYSIS
ACID OR PARR DIGESTION
DILUTE TO 10 OR 100ml
AA ANALYSIS
COMBINE 1μ AND FILTER
ASH
ACID OR PARR DIGESTION
FILTER
PARR DIGESTION
FILTER
REMAINDER
SOXHLET EXTRACTION CH2Cl2
MEASURE VOLUME
TCO ANALYSIS C7-C16
2-4g REMOVED
PARR ACID DIGESTION
AA ANALYSIS
COMBINE AND MEASURE VOLUME
TCO ANALYSIS C7-C16
COMBINE
ACIDIFY
AA ANALYSIS
COMBINE 10μ AND 3μ
PROCEED AS INDICATED
SOXHLET EXTRACTION CH2Cl2
MEASURE SAMPLE VOLUME
TCO ANALYSIS C7-C16
CONCENTRATE AS NECESSARY (K-D) (1)
PROCEED AS INDICATED
COMBINE
DILUTE TO 10 OR 100ml
AA ANALYSIS
COMBINE
CONCENTRATE AS NECESSARY (K-D) (1)
TCO + GRAV ≥100 mg/ml
REMAINDER
YES
NO
GRAV ALIQUOT FOR IR
DEPOSIT ON SALT PLATE
IR ANALYSIS
ALIQUOT FOR LC (1)
LC SEPARATION (5)
CONCENTRATE TO NOT GREATER THAN 100 mg/ml BUT NOT LESS THAN 2 ml
1 ml ALIQUOT
TCO + GRAV ≥15 mg/ml (3,4)
YES
NO
STOP
1 ml ALIQUOT FOR LC (2)
SECOND AND THIRD IMPINGER
ACIDIFY HNO3
AA ANALYSIS Sb, Hg, As

SASS analysis procedures

]


ALIQUOT FOR LC 15-100 mg
A-195198
SOLVENT EXCHANGE TO HEXANE
LC
1
2
3
4
5
6
7
8
GRAV + TCO
XAD: [≥0.5mg(f)/m³]
ASH: [≥1mg(f)/Kg]
(8)
YES
NO
STOP
GC/MS (6)
ALIQUOT
TCO
GRAV
IR
GRAV
XAD: [≥0.5mg(f)/m³]
ASH: [≥1mg(f)/Kg]
(8)
NO
STOP
YES
LRMS

SASS analysis procedure liquid chromatography

APPENDIX C

TRACE ELEMENT CONCENTRATIONS

```
07/19/79  13:12:55 LIPS   0289AA529    LIPS          4      300                           DATE 071979         PAGE    25

                                          SPREADER STOKER INDUSTRIAL BOILER
                                 TRACE ELEMENT CONCENTRATION - (PPM) -        FUEL INLET

                      TRACE ELEMENTS                      TEST CONDITION

                      CATIONS                               BASELINE               LOW NOX

                        ANTIMONY                        <     .200          <     .200
                        ARSENIC                               .800                .800
                        BARIUM                                71.0                68.0
                        BERYLLIUM                             2.40                2.40
                        BISMUTH                         <     3.00          <     3.00

                        BORON                                 20.0                5.00
                        CADMIUM                         <     .100+00       <     .100+00
                        CHROMIUM                              13.0                13.0
                        COBALT                                3.90                4.60
                        COPPER                                17.0                16.0

                        IRON                                  .371+04             .301+04
                        LEAD                            <     5.00          <     6.00
                        MANGANESE                             23.0                10.0
                        MERCURY                               .400-01             .500-01
                        MOLYBDENUM                      <     6.00          <     7.00

                        NICKEL                                9.30                9.30
                        SELENIUM                              1.60                1.40
                        TELLURIUM                       <     .200          <     .200
                        THALLIUM                        <     4.00          <    5.000
                        TIN                                   .800                .600

                        TITANIUM                              .110+04             .113+04
                        URANIUM                               .590                .610
                        VANADIUM                              26.0                21.0
                        ZINC                                  8.60                11.0
                        ZIRCONIUM                             42.0                75.0

                      ANIONS
                        CHLORIDE                        *     .000          *     .000
                        FLUORIDE                        *     .000          *     .000
                        CYANIDE                         *     .000          *     .000
                        NITRATE                         *     .000          *     .000
                        SULFATE                         *     .000          *     .000

                        AMMONIUM                        *     .000          *     .000
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07/19/79  13:12:55 LIPS   0289AA529    LIPS          4     300                           DATE 071979        PAGE    26

                                 SPREADER STOKER INDUSTRIAL BOILER
                           TRACE ELEMENT CONCENTRATION - (PPM) -          BOTTOM ASH

                  TRACE ELEMENTS                    TEST CONDITION

                  CATIONS                             BASELINE              LOW NOX

                    ANTIMONY                      <      .600         <     .600
                    ARSENIC                       <     2.00          <    2.00
                    BARIUM                        <     10.0          <    10.0
                    BERYLLIUM                     <     .200          <    .200
                    BISMUTH                             19.0               19.0

                    BORON                         <     .200+04       <    .200+04
                    CADMIUM                             .840               .840
                    CHROMIUM                            110.               110.
                    COBALT                              16.0               16.0
                    COPPER                              96.0               96.0

                    IRON                                .200+05            .200+05
                    LEAD                                5.80               5.80
                    MANGANESE                           460.               460.
                    MERCURY                       <     .700          <    .700
                    MOLYBDENUM                    <     3.00          <    3.00

                    NICKEL                              48.0               48.0
                    SELENIUM                      <     .300          <    .300
                    TELLURIUM                           3.50               3.50
                    THALLIUM                      <     3.00          <    3.00
                    TIN                                 210.               210.

                    TITANIUM                            .890+04            .890+04
                    URANIUM                       *     .000          *    .000
                    VANADIUM                            190.               190.
                    ZINC                                11.0               11.0
                    ZIRCONIUM                     *     .000          *    .000

                  ANIONS
                    CHLORIDE                      <     19.8          <    19.8
                    FLUORIDE                      <     .100+00       <    .100+00
                    CYANIDE                       <     2.50          <    2.50
                    NITRATE                             2.70               2.70
                    SULFATE                             359.               359.

                    AMMONIUM                            9.10               9.10
```

SAMPLE NOT TAKEN, ASSUMED SAME AS LEA

```
                         SPREADER STOKER INDUSTRIAL BOILER
               TRACE ELEMENT CONCENTRATION - (PPM) -   MECHANICAL HOPPER ASH

TRACE ELEMENTS                  TEST CONDITION

CATIONS                             BASELINE              LOW NOX

  ANTIMONY                      <     .600         <     .600
  ARSENIC                             2.00         <     2.00
  BARIUM                              83.0               370.
  BERYLLIUM                           24.0               5.00
  BISMUTH                       <     .800         <     1.00

  BORON                               .500+04      <     .200+04
  CADMIUM                       <     .300-01            .490
  CHROMIUM                            .900+04            64.0
  COBALT                              34.0         <     .100+00
  COPPER                              46.0               24.0

  IRON                                .140+05            .800+04
  LEAD                                420.               6.90
  MANGANESE                           310.               250.
  MERCURY                       <     .900-01      <     .700
  MOLYBDENUM                    <     .500         <     3.00

  NICKEL                              40.0               30.0
  SELENIUM                      <     1.00         <     .300
  TELLURIUM                     <     .600               .500
  THALLIUM                      <     5.00         <     3.00
  TIN                                 200.               62.0

  TITANIUM                            .240+04            .140+04
  URANIUM                       *     .000         *     .000
  VANADIUM                            54.0               7.10
  ZINC                                24.0               22.0
  ZIRCONIUM                     *     .000         *     .000

ANIONS
  CHLORIDE                      <     19.9         <     20.0
  FLUORIDE                            2.60               6.20
  CYANIDE                       <     2.50         <     2.50
  NITRATE                       <     .300         <     .300
  SULFATE                             .124+04            849.

  AMMONIUM                      <     2.50         <     2.50
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                       SPREADER STOKER INDUSTRIAL BOILER
              TRACE ELEMENT CONCENTRATION - (PPM) -      BOILER OUTLET

                              10 MICRON CYCLONE

TRACE ELEMENTS                   TEST CONDITION

CATIONS                            BASELINE           LOW NOX

  ANTIMONY                      <   .600               .700
  ARSENIC                          13.0               12.0
  BARIUM                            .260+04            .480+04
  BERYLLIUM                        56.0               44.0
  BISMUTH                          1.00           <   .800

  BORON                             .340+04       <   .100+04
  CADMIUM                       <   .700-01       <   .700-01
  CHROMIUM                      <   .500          <   .500
  COBALT                        <   .300-01       <   .300-01
  COPPER                            .160               .170

  IRON                             16.0               12.0
  LEAD                          <   .200          <   .200
  MANGANESE                         .170               .200
  MERCURY                           .200          <   .900-01
  MOLYBDENUM                       20.0               19.0

  NICKEL                        <   .800          <   .900
  SELENIUM                      <  1.00               5.90
  TELLURIUM                     <   .600          <   .600
  THALLIUM                      <  5.00           <  5.00
  TIN                           <  5.00           <  5.00

  TITANIUM                      <  9.00           <  9.00
  URANIUM                       *   .000          *   .000
  VANADIUM                         4.80               4.80
  ZINC                              .600-01            .600-01
  ZIRCONIUM                     *   .000          *   .000

ANIONS
  CHLORIDE                      <  19.9           <  22.2
  FLUORIDE                         2.60               11.9
  CYANIDE                       <  2.50           <  2.80
  NITRATE                           .300          <   .300
  SULFATE                           .148+04            .152+04

  AMMONIUM                      <  2.50           <  2.80
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07/19/79  13:12:55 LIPS   0289AA529    LIPS          4      300                            DATE 071979         PAGE     29

                                           SPREADER STOKER INDUSTRIAL BOILER
                                    TRACE ELEMENT CONCENTRATION - (PPM) -       BOILER OUTLET

                                                   3 MICRON CYCLONE

                  TRACE ELEMENTS                        TEST CONDITION

                  CATIONS                                 BASELINE            LOW NOX

                    ANTIMONY                                4.80               4.80
                    ARSENIC                                 62.0               59.0
                    BARIUM                                  .220+04            .260+04
                    BERYLLIUM                               22.0               1.80
                    BISMUTH                                 2.60               4.40

                    BORON                           <       .200+04            .180+04
                    CADMIUM                         <       .600-01            .230
                    CHROMIUM                        <       .400          <    .400
                    COBALT                          <       .300-01       <    .300-01
                    COPPER                                  .200               .330

                    IRON                                    5.60               12.0
                    LEAD                            <       .900-01       <    .900-01
                    MANGANESE                               .140               .170
                    MERCURY                         <       .200          <    .900-01
                    MOLYBDENUM                              26.0               24.0

                    NICKEL                          <       .700          <    .700
                    SELENIUM                        <       1.00               9.00
                    TELLURIUM                       <       .500          <    .500
                    THALLIUM                        <       4.00          <    4.00
                    TIN                             <       4.00          <    4.00

                    TITANIUM                        <       10.0               11.0
                    URANIUM                         *       .000          *    .000
                    VANADIUM                                3.90               4.20
                    ZINC                                    .100+00            .210
                    ZIRCONIUM                       *       .000          *    .000

                  ANIONS
                    CHLORIDE                        <       19.0          *    .000
                    FLUORIDE                        <       .100+00       *    .000
                    CYANIDE                                 7.10          *    .000
                    NITRATE                                 3.10          *    .000
                    SULFATE                                 .635+04       *    .000

                    AMMONIUM                                27.4          *    .000
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                                   SPREADER STOKER INDUSTRIAL BOILER
                             TRACE ELEMENT CONCENTRATION - (PPM) -      BOILER OUTLET

                                          1 MICRON CYCLONE

                 TRACE ELEMENTS                    TEST CONDITION

                 CATIONS                              BASELINE             LOW NOX

                   ANTIMONY                            20.0                 11.0
                   ARSENIC                             140.                 190.
                   BARIUM                              440.                 .310+04
                   BERYLLIUM                           8.20                 61.0
                   BISMUTH                             2.70                 10.0

                   BORON                          <    .200+04              .370+04
                   CADMIUM                             .440                 1.00
                   CHROMIUM                       <    .400            <    .500
                   COBALT                         <    .300-01         <    .300-01
                   COPPER                              .250                 .520

                   IRON                                6.20                 19.0
                   LEAD                           <    .900-01         <    .200
                   MANGANESE                           .170                 .270
                   MERCURY                        <    .900-01         <    .900-01
                   MOLYBDENUM                          24.0                 46.0

                   NICKEL                         <    .700            <    .800
                   SELENIUM                            21.0                 3.70
                   TELLURIUM                      <    .500            <    .500
                   THALLIUM                       <    4.00            <    4.00
                   TIN                            <    4.00            <    4.00

                   TITANIUM                            11.0                 12.0
                   URANIUM                        *    .000            *    .000
                   VANADIUM                            4.10                 4.50
                   ZINC                                .210                 .570
                   ZIRCONIUM                      *    .000            *    .000

                 ANIONS
                   CHLORIDE                       *    .000            *    .000
                   FLUORIDE                       *    .000            *    .000
                   CYANIDE                        *    .000            *    .000
                   NITRATE                        *    .000            *    .000
                   SULFATE                        *    .000            *    .000

                   AMMONIUM                       *    .000            *    .000
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                              SPREADER STOKER INDUSTRIAL BOILER
                       TRACE ELEMENT CONCENTRATION - (PPM) -      BOILER OUTLET

                                            FILTER

          TRACE ELEMENTS                TEST CONDITION

          CATIONS                          BASELINE           LOW NOX

            ANTIMONY                         250.         <    20.0
            ARSENIC                          .250+04           890.
            BARIUM                           .180+04           .230+05
            BERYLLIUM                        .320              2.10
            BISMUTH                          20.0         <    20.0

            BORON                            .200+04      <    .200+04
            CADMIUM                          82.0              35.0
            CHROMIUM                    <    .600         <    3.00
            COBALT                           700.              230.
            COPPER                           .230+04           4.10

            IRON                        <    .400-01      <    .200
            LEAD                        <    .200         <    1.00
            MANGANESE                        100.              240.
            MERCURY                          .600              1.30
            MOLYBDENUM                       250.              320.

            NICKEL                           .110+04           920.
            SELENIUM                         120.              64.0
            TELLURIUM                        6.00         <    6.00
            THALLIUM                         13.0         <    7.00
            TIN                              70.0         <    100.

            TITANIUM                    <    20.0              80.0
            URANIUM                     *    .000         *    .000
            VANADIUM                         .140+04           520.
            ZINC                             2.60              4.70
            ZIRCONIUM                   *    .000         *    .000

          ANIONS
            CHLORIDE                    *    .000         *    .000
            FLUORIDE                    *    .000         *    .000
            CYANIDE                     *    .000         *    .000
            NITRATE                     *    .000         *    .000
            SULFATE                     *    .000         *    .000

            AMMONIUM                    *    .000         *    .000
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                          SPREADER STOKER INDUSTRIAL BOILER
                    TRACE ELEMENT CONCENTRATION - (PPM) -      BOILER OUTLET

                                  XAD-2 CARTRIDGE

     TRACE ELEMENTS                  TEST CONDITION

     CATIONS                            BASELINE             LOW NOX

       ANTIMONY                     <     .500          <     .500
       ARSENIC                      <     .500          <     .500
       BARIUM                       <     .400-01             4.00
       BERYLLIUM                          .500-01             .250-01
       BISMUTH                      <     .400          <     .400

       BORON                        <     .100+04       <     900.
       CADMIUM                      <     .400-01       <     .400-01
       CHROMIUM                     <     .400                2.50
       COBALT                       <     .300-01             .500
       COPPER                             .510          <     .300-02

       IRON                               65.0                19.0
       LEAD                               .360                .730
       MANGANESE                          .140                .150
       MERCURY                      <     .900-01             .730
       MOLYBDENUM                   <     .600          <     .600

       NICKEL                       <     .500          <     .500
       SELENIUM                     <     .500          <     .500
       TELLURIUM                    <     .500          <     .500
       THALLIUM                     <     .800          <     .500
       TIN                                1.50          <     .700

       TITANIUM                           20.0                15.0
       URANIUM                      *     .000          *     .000
       VANADIUM                           2.80                2.50
       ZINC                               .800-01             .800-01
       ZIRCONIUM                    *     .000          *     .000

     ANIONS
       CHLORIDE                     *     .000          *     .000
       FLUORIDE                     *     .000          *     .000
       CYANIDE                      *     .000          *     .000
       NITRATE                      *     .000          *     .000
       SULFATE                      *     .000          *     .000

       AMMONIUM                     *     .000          *     .000
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                                   SPREADER STOKER INDUSTRIAL BOILER
                           TRACE ELEMENT CONCENTRATION - (PPM) -      BOILER OUTLET

                                          FIRST IMPINGERS

                     TRACE ELEMENTS                     TEST CONDITION

                     CATIONS                               BASELINE             LOW NOX

                       ANTIMONY                     <    .400-02        <    .300-02
                       ARSENIC                           .210-01             .250-01
                       BARIUM                            .360-01             .590
                       BERYLLIUM                         .400-03             .850-02
                       BISMUTH                      <    .200-02             .610-01

                       BORON                             20.0                27.0
                       CADMIUM                           .100-01             .200-01
                       CHROMIUM                     <    .200-02             .700-02
                       COBALT                            .100-03             .300-03
                       COPPER                            .500-04             .240-01

                       IRON                              .280                .330
                       LEAD                         <    .100-02        <    .100-02
                       MANGANESE                         .500-03             .160-02
                       MERCURY                      <    .100-02        <    .100-02
                       MOLYBDENUM                        .220                .430

                       NICKEL                            3.40                9.00
                       SELENIUM                          .100-01             .560-01
                       TELLURIUM                         .500-02        <    .300-02
                       THALLIUM                          .100-01             .800-02
                       TIN                               .130                .630-01

                       TITANIUM                     <    .600-01        <    .600-01
                       URANIUM                      *    .000           *    .000
                       VANADIUM                          .700-02        <    .200-02
                       ZINC                              .200-03             .280-02
                       ZIRCONIUM                    *    .000           *    .000

                     ANIONS
                       CHLORIDE                     *    .000           *    .000
                       FLUORIDE                     *    .000           *    .000
                       CYANIDE                      *    .000           *    .000
                       NITRATE                      *    .000           *    .000
                       SULFATE                      *    .000           *    .000

                       AMMONIUM                     *    .000           *    .000
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                              SPREADER STOKER INDUSTRIAL BOILER
                      TRACE ELEMENT CONCENTRATION - (PPM) -      BOILER OUTLET

                                     2ND & 3RD IMPINGERS

               TRACE ELEMENTS                     TEST CONDITION

               CATIONS                              BASELINE            LOW NOX

                 ANTIMONY                             .400-02      <     .300-02
                 ARSENIC                       <      .700-02      <     .600-02
                 BARIUM                        *      .000         *     .000
                 BERYLLIUM                     *      .000         *     .000
                 BISMUTH                       *      .000         *     .000

                 BORON                         *      .000         *     .000
                 CADMIUM                       *      .000         *     .000
                 CHROMIUM                      *      .000         *     .000
                 COBALT                        *      .000         *     .000
                 COPPER                        *      .000         *     .000

                 IRON                          *      .000         *     .000
                 LEAD                          *      .000         *     .000
                 MANGANESE                     *      .000         *     .000
                 MERCURY                       <      .100-02            .130-01
                 MOLYBDENUM                    *      .000         *     .000

                 NICKEL                        *      .000         *     .000
                 SELENIUM                      *      .000         *     .000
                 TELLURIUM                     *      .000         *     .000
                 THALLIUM                      *      .000         *     .000
                 TIN                           *      .000         *     .000

                 TITANIUM                      *      .000         *     .000
                 URANIUM                       *      .000         *     .000
                 VANADIUM                      *      .000         *     .000
                 ZINC                          *      .000         *     .000
                 ZIRCONIUM                     *      .000         *     .000

               ANIONS
                 CHLORIDE                      *      .000         *     .000
                 FLUORIDE                      *      .000         *     .000
                 CYANIDE                       *      .000         *     .000
                 NITRATE                       *      .000         *     .000
                 SULFATE                       *      .000         *     .000

                 AMMONIUM                      *      .000         *     .000
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                       SPREADER STOKER INDUSTRIAL BOILER
                  TRACE ELEMENT CONCENTRATION - (PPM) -      ESP HOPPER ASH

TRACE ELEMENTS                TEST CONDITION

CATIONS                         BASELINE          LOW NOX

  ANTIMONY                        27.0              31.0
  ARSENIC                         740.              590.
  BARIUM                          .440+04           .280+04
  BERYLLIUM                       77.0              69.0
  BISMUTH                     <   .600              11.0

  BORON                       <   .200+04           .270+04
  CADMIUM                         1.00              3.00
  CHROMIUM                    <   .400          <   .300
  COBALT                      <   .300-01       <   .200-01
  COPPER                          .620              .760

  IRON                            30.0              51.0
  LEAD                        <   .900-01       <   .900-01
  MANGANESE                       .210              .260
  MERCURY                         .200              .200
  MOLYBDENUM                      21.0              26.0

  NICKEL                      <   .700          <   .600
  SELENIUM                        84.0              120.
  TELLURIUM                   <   .500          <   .400
  THALLIUM                    <   4.00          <   4.00
  TIN                             33.0              45.0

  TITANIUM                        14.0              8.50
  URANIUM                     *   .000          *   .000
  VANADIUM                        4.60              3.80
  ZINC                            .570              .820
  ZIRCONIUM                   *   .000          *   .000

ANIONS
  CHLORIDE                    <   20.0          <   19.9
  FLUORIDE                        38.1              62.2
  CYANIDE                     <   .150          <   .560
  NITRATE                         1.80              4.80
  SULFATE                         .110+05           .230+05

  AMMONIUM                        .180              450.
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                              SPREADER STOKER INDUSTRIAL BOILER
                       TRACE ELEMENT CONCENTRATION - (PPM) -        ESP OUTLET

                                      10 MICRON CYCLONE

              TRACE ELEMENTS                  TEST CONDITION

              CATIONS                          BASELINE          LOW NOX

                ANTIMONY                    *    .000        *    .000
                ARSENIC                     *    .000        *    .000
                BARIUM                      *    .000        *    .000
                BERYLLIUM                   *    .000        *    .000
                BISMUTH                     *    .000        *    .000

                BORON                       *    .000        *    .000
                CADMIUM                     *    .000        *    .000
                CHROMIUM                    *    .000        *    .000
                COBALT                      *    .000        *    .000
                COPPER                      *    .000        *    .000

                IRON                        *    .000        *    .000
                LEAD                        *    .000        *    .000
                MANGANESE                   *    .000        *    .000
                MERCURY                     *    .000        *    .000
                MOLYBDENUM                  *    .000        *    .000

                NICKEL                      *    .000        *    .000
                SELENIUM                    *    .000        *    .000
                TELLURIUM                   *    .000        *    .000
                THALLIUM                    *    .000        *    .000
                TIN                         *    .000        *    .000

                TITANIUM                    *    .000        *    .000
                URANIUM                     *    .000        *    .000
                VANADIUM                    *    .000        *    .000
                ZINC                        *    .000        *    .000
                ZIRCONIUM                   *    .000        *    .000

              ANIONS
                CHLORIDE                    *    .000        *    .000
                FLUORIDE                    *    .000        *    .000
                CYANIDE                     *    .000        *    .000
                NITRATE                     *    .000        *    .000
                SULFATE                     *    .000        *    .000

                AMMONIUM                    *    .000        *    .000
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                                         SPREADER STOKER INDUSTRIAL BOILER
                                 TRACE ELEMENT CONCENTRATION - (PPM) -          ESP OUTLET

                                                3 MICRON CYCLONE

                         TRACE ELEMENTS                        TEST CONDITION

                         CATIONS                                  BASELINE             LOW NOX

                           ANTIMONY                          *     .000          *     .000
                           ARSENIC                           *     .000          *     .000
                           BARIUM                            *     .000          *     .000
                           BERYLLIUM                         *     .000          *     .000
                           BISMUTH                           *     .000          *     .000

                           BORON                             *     .000          *     .000
                           CADMIUM                           *     .000          *     .000
                           CHROMIUM                          *     .000          *     .000
                           COBALT                            *     .000          *     .000
                           COPPER                            *     .000          *     .000

                           IRON                              *     .000          *     .000
                           LEAD                              *     .000          *     .000
                           MANGANESE                         *     .000          *     .000
                           MERCURY                           *     .000          *     .000
                           MOLYBDENUM                        *     .000          *     .000

                           NICKEL                            *     .000          *     .000
                           SELENIUM                          *     .000          *     .000
                           TELLURIUM                         *     .000          *     .000
                           THALLIUM                          *     .000          *     .000
                           TIN                               *     .000          *     .000

                           TITANIUM                          *     .000          *     .000
                           URANIUM                           *     .000          *     .000
                           VANADIUM                          *     .000          *     .000
                           ZINC                              *     .000          *     .000
                           ZIRCONIUM                         *     .000          *     .000
                         ANIONS
                           CHLORIDE                          *     .000          *     .000
                           FLUORIDE                          *     .000          *     .000
                           CYANIDE                           *     .000          *     .000
                           NITRATE                           *     .000          *     .000
                           SULFATE                           *     .000          *     .000

                           AMMONIUM                          *     .000          *     .000
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07/19/79  13:12:55 LIPS   0289AA529    LIPS           4     300                           DATE 071979          PAGE    38

                                   SPREADER STOKER INDUSTRIAL BOILER
                            TRACE ELEMENT CONCENTRATION - (PPM) -         ESP OUTLET

                                           1 MICRON CYCLONE

                     TRACE ELEMENTS                      TEST CONDITION

                     CATIONS                                BASELINE              LOW NOX

                       ANTIMONY                          *     .000           *     .000
                       ARSENIC                           *     .000           *     .000
                       BARIUM                            *     .000           *     .000
                       BERYLLIUM                         *     .000           *     .000
                       BISMUTH                           *     .000           *     .000

                       BORON                             *     .000           *     .000
                       CADMIUM                           *     .000           *     .000
                       CHROMIUM                          *     .000           *     .000
                       COBALT                            *     .000           *     .000
                       COPPER                            *     .000           *     .000

                       IRON                              *     .000           *     .000
                       LEAD                              *     .000           *     .000
                       MANGANESE                         *     .000           *     .000
                       MERCURY                           *     .000           *     .000
                       MOLYBDENUM                        *     .000           *     .000

                       NICKEL                            *     .000           *     .000
                       SELENIUM                          *     .000           *     .000
                       TELLURIUM                         *     .000           *     .000
                       THALLIUM                          *     .000           *     .000
                       TIN                               *     .000           *     .000

                       TITANIUM                          *     .000           *     .000
                       URANIUM                           *     .000           *     .000
                       VANADIUM                          *     .000           *     .000
                       ZINC                              *     .000           *     .000
                       ZIRCONIUM                         *     .000           *     .000

                     ANIONS
                       CHLORIDE                          *     .000           *     .000
                       FLUORIDE                          *     .000           *     .000
                       CYANIDE                           *     .000           *     .000
                       NITRATE                           *     .000           *     .000
                       SULFATE                           *     .000           *     .000

                       AMMONIUM                          *     .000           *     .000
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07/19/79  13:12:55 LIPS   0289AA529    LIPS         4     300                      DATE 071979        PAGE   39

                                  SPREADER STOKER INDUSTRIAL BOILER
                           TRACE ELEMENT CONCENTRATION - (PPM) -        ESP OUTLET

                                               FILTER

        TRACE ELEMENTS                       TEST CONDITION

        CATIONS                                 BASELINE             LOW NOX

          ANTIMONY                               60.0           <    40.0
          ARSENIC                                .170+04              .130+04
          BARIUM                                 .690+04        <    .600
          BERYLLIUM                              4.00                 5.00
          BISMUTH                                40.0                 50.0

          BORON                            <     .800+04              .360+05
          CADMIUM                                19.0                 150.
          CHROMIUM                               42.0                 10.0
          COBALT                                 920.                 89.0
          COPPER                                 .230+04              .900

          IRON                                   31.0           <    .300
          LEAD                             <     .300           <    2.00
          MANGANESE                              180.                 410.
          MERCURY                                1.20                 1.80
          MOLYBDENUM                             300.                 110.

          NICKEL                                 .230+04              450.
          SELENIUM                               250.                 100.
          TELLURIUM                              15.0           <    10.0
          THALLIUM                               4.00           <    10.0
          TIN                                    250.           <    200.

          TITANIUM                         <     20.0           <    90.0
          URANIUM                          *     .000           *    .000
          VANADIUM                               .110+04              80.0
          ZINC                                   2.90           <    .200
          ZIRCONIUM                        *     .000           *    .000

        ANIONS
          CHLORIDE                         *     .000           *    .000
          FLUORIDE                         *     .000           *    .000
          CYANIDE                          *     .000           *    .000
          NITRATE                          *     .000           *    .000
          SULFATE                          *     .000           *    .000

          AMMONIUM                         *     .000           *    .000
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                            SPREADER STOKER INDUSTRIAL BOILER
                    TRACE ELEMENT CONCENTRATION - (PPM) -        ESP OUTLET

                                   XAD-2 CARTRIDGE

            TRACE ELEMENTS               TEST CONDITION

            CATIONS                         BASELINE            LOW NOX

              ANTIMONY                 <     .500          <     .500
              ARSENIC                  <     .500          <     .500
              BARIUM                         10.0          <     .400-01
              BERYLLIUM                      .220          <     .500-02
              BISMUTH                  <     .400          <     .400

              BORON                    <     .100+04       <     900.
              CADMIUM                  <     .400-01       <     .400-01
              CHROMIUM                       14.0                4.00
              COBALT                         1.40                .840
              COPPER                         5.50          <     .300-02

              IRON                           61.0                7.80
              LEAD                           .270          <     .900-01
              MANGANESE                      2.10          <     .800-03
              MERCURY                        .510                .900-01
              MOLYBDENUM               <     .500                26.0

              NICKEL                         6.20          <     .500
              SELENIUM                       2.00                2.20
              TELLURIUM                <     .400                .550
              THALLIUM                 <     .400          <     .400
              TIN                      <     .700          <     .700

              TITANIUM                       13.0                11.0
              URANIUM                  *     .000          *     .000
              VANADIUM                       24.0                2.00
              ZINC                           2.40          <     .800-02
              ZIRCONIUM                *     .000          *     .000

            ANIONS
              CHLORIDE                 *     .000          *     .000
              FLUORIDE                 *     .000          *     .000
              CYANIDE                  *     .000          *     .000
              NITRATE                  *     .000          *     .000
              SULFATE                  *     .000          *     .000

              AMMONIUM                 *     .000          *     .000
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                          SPREADER STOKER INDUSTRIAL BOILER
                    TRACE ELEMENT CONCENTRATION - (PPM) -         ESP OUTLET

                                    FIRST IMPINGERS

           TRACE ELEMENTS                      TEST CONDITION

           CATIONS                               BASELINE              LOW NOX

             ANTIMONY                    <     .300-02          <     .300-02
             ARSENIC                           .170-01                .320-01
             BARIUM                            .270-01                .380-01
             BERYLLIUM                         .390-02                .150-02
             BISMUTH                     <     .400-02          <     .400-02

             BORON                             47.0                   48.0
             CADMIUM                           130.-04                .160-01
             CHROMIUM                          .650-01                .540-01
             COBALT                            .130-02                .120-02
             COPPER                            .800-04                .200-03

             IRON                              .650                   .590
             LEAD                        <     .100-02          <     .100-02
             MANGANESE                         .710-02                .650-02
             MERCURY                           .500-02                .110-01
             MOLYBDENUM                        5.50                   1.50

             NICKEL                            45.0                   35.0
             SELENIUM                          .130-01                .170-01
             TELLURIUM                         .500-02                .800-02
             THALLIUM                    <     .500-02                .500-02
             TIN                               .370-01          <     .100-01

             TITANIUM                    <     .500-01          <     .400-01
             URANIUM                     *     .000             *     .000
             VANADIUM                          .270                   .120
             ZINC                              .100-03                .300-03
             ZIRCONIUM                   *     .000             *     .000

           ANIONS
             CHLORIDE                    *     .000             *     .000
             FLUORIDE                    *     .000             *     .000
             CYANIDE                     *     .000             *     .000
             NITRATE                     *     .000             *     .000
             SULFATE                     *     .000             *     .000

             AMMONIUM                    *     .000             *     .000
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                         SPREADER STOKER INDUSTRIAL BOILER
                    TRACE ELEMENT CONCENTRATION - (PPM) -        ESP OUTLET

                                  2ND & 3RD IMPINGERS

        TRACE ELEMENTS                  TEST CONDITION

        CATIONS                           BASELINE          LOW NOX

          ANTIMONY                   <     .400-02     <     .400-02
          ARSENIC                    <     .700-02     <     .700-02
          BARIUM                     *     .000        *     .000
          BERYLLIUM                  *     .000        *     .000
          BISMUTH                    *     .000        *     .000

          BORON                      *     .000        *     .000
          CADMIUM                    *     .000        *     .000
          CHROMIUM                   *     .000        *     .000
          COBALT                     *     .000        *     .000
          COPPER                     *     .000        *     .000

          IRON                       *     .000        *     .000
          LEAD                       *     .000        *     .000
          MANGANESE                  *     .000        *     .000
          MERCURY                    <     .100-02           .300-02
          MOLYBDENUM                 *     .000        *     .000

          NICKEL                     *     .000        *     .000
          SELENIUM                   *     .000        *     .000
          TELLURIUM                  *     .000        *     .000
          THALLIUM                   *     .000        *     .000
          TIN                        *     .000        *     .000

          TITANIUM                   *     .000        *     .000
          URANIUM                    *     .000        *     .000
          VANADIUM                   *     .000        *     .000
          ZINC                       *     .000        *     .000
          ZIRCONIUM                  *     .000        *     .000

        ANIONS
          CHLORIDE                   *     .000        *     .000
          FLUORIDE                   *     .000        *     .000
          CYANIDE                    *     .000        *     .000
          NITRATE                    *     .000        *     .000
          SULFATE                    *     .000        *     .000

          AMMONIUM                   *     .000        *     .000
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APPENDIX D

TRACE ELEMENT FLOW RATES

Symbols appearing in the tables:

DSCM	Dry Standard Cubic Meter
ESP	Electrostatic Precipitator
KG	Kilogram
MCG	Microgram
MIN	Minute
PPM	Part per million by weight
<	Less than
*	Sample not analyzed for the particular element/or ionic specie
N	Sample not analyzed
-	Concentration in the sample is less than the concentration in the blank

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APPENDIX D-1

TRACE ELEMENT FLOW RATES

(kilograms per minute)

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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- FUEL INLET

TRACE ELEMENTS	TEST CONDITION			
	BASELINE		LOW NOX	
CATIONS				
ANTIMONY	<	.291-04	<	.287-04
ARSENIC		.116-03		.115-03
BARIUM		.103-01		.975-02
BERYLLIUM		.347-03		.344-03
BISMUTH	<	.436-03	<	.430-03
BORON		.291-02		.717-03
CADMIUM	<	.145-04	<	.143-04
CHROMIUM		.189-02		.186-02
COBALT		.567-03		.659-03
COPPER		.247-02		.229-02
IRON		.537		.431
LEAD	<	.726-03	<	.860-03
MANGANESE		.334-02		.143-02
MERCURY		.581-05		.717-05
MOLYBDENUM	<	.872-03	<	.100-02
NICKEL		.135-02		.133-02
SELENIUM		.232-03		.201-03
TELLURIUM	<	.291-04	<	.287-04
THALLIUM	<	.581-03	<	.717-03
TIN		.116-03		.860-04
TITANIUM		.160		.162
URANIUM		.857-04		.874-04
VANADIUM		.378-02		.301-02
ZINC		.125-02		.158-02
ZIRCONIUM		.610-02		.107-01
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOTTOM ASH

TRACE ELEMENTS	TEST CONDITION			
		BASELINE		LOW NOX
CATIONS				
ANTIMONY	<	.314-05	<	.338-05
ARSENIC	<	.105-04	<	.113-04
BARIUM	<	.525-04	<	.563-04
BERYLLIUM	<	.105-05	<	.113-05
BISMUTH		.995-04		.107-03
BORON	<	.105-01	<	.113-01
CADMIUM		.440-05		.473-05
CHROMIUM		.576-03		.619-03
COBALT		.838-04		.901-04
COPPER		.503-03		.540-03
IRON		.105		.113
LEAD		.304-04		.327-04
MANGANESE		.241-02		.259-02
MERCURY	<	.366-05	<	.394-05
MOLYBDENUM	<	.157-04	<	.169-04
NICKEL		.251-03		.270-03
SELENIUM	<	.157-05	<	.169-05
TELLURIUM		.183-04		.197-04
THALLIUM	<	.157-04	<	.169-04
TIN		.110-02		.118-02
TITANIUM		.466-01		.501-01
URANIUM	*	.000	*	.000
VANADIUM		.995-03		.107-02
ZINC		.576-04		.619-04
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	.104-03	<	.111-03
FLUORIDE	<	.523-06	<	.563-06
CYANIDE	<	.131-04	<	.141-04
NITRATE		.141-04		.152-04
SULFATE		.188-02		.202-02
AMMONIUM		.476-04		.512-04

SAMPLE NOT TAKEN ASSUMED SAME PPM AS LEA

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- MECHANICAL HOPPER ASH

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	< .711-05	< .547-05
ARSENIC	.237-04	< .182-04
BARIUM	.984-03	.337-02
BERYLLIUM	.284-03	.456-04
BISMUTH	< .948-05	< .912-05
BORON	.592-01	< .182-01
CADMIUM	< .355-06	.447-05
CHROMIUM	.107	.583-03
COBALT	.403-03	< .912-06
COPPER	.545-03	.219-03
IRON	.166	.729-01
LEAD	.498-02	.629-04
MANGANESE	.367-02	.228-02
MERCURY	< .107-05	< .638-05
MOLYBDENUM	< .592-05	< .273-04
NICKEL	.474-03	.273-03
SELENIUM	< .118-04	< .273-05
TELLURIUM	< .711-05	.456-05
THALLIUM	< .592-04	< .273-04
TIN	.237-02	.565-03
TITANIUM	.284-01	.128-01
URANIUM	* .000	* .000
VANADIUM	.640-03	.647-04
ZINC	.284-03	.201-03
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	< .236-03	< .182-03
FLUORIDE	.308-04	.565-04
CYANIDE	< .296-04	< .228-04
NITRATE	< .355-05	< .273-05
SULFATE	.146-01	.774-02
AMMONIUM	< .296-04	< .228-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

10 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	< .148-04	.122-04
ARSENIC	.320-03	.210-03
BARIUM	.639-01	.839-01
BERYLLIUM	.138-02	.769-03
BISMUTH	.246-04	< .140-04
BORON	.836-01	< .175-01
CADMIUM	< .172-05	< .122-05
CHROMIUM	< .123-04	< .874-05
COBALT	< .730-06	< .525-06
COPPER	.395-05	.297-05
IRON	.393-03	.210-03
LEAD	< .492-05	< .350-05
MANGANESE	.418-05	.350-05
MERCURY	.492-05	< .157-05
MOLYBDENUM	.492-03	.332-03
NICKEL	< .197-04	< .157-04
SELENIUM	< .246-04	.103-03
TELLURIUM	< .148-04	< .105-04
THALLIUM	< .123-03	< .874-04
TIN	< .123-03	< .874-04
TITANIUM	< .221-03	< .157-03
URANIUM	* .000	* .000
VANADIUM	.118-03	.839-04
ZINC	.148-05	.105-05
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	< .489-03	< .388-03
FLUORIDE	.639-04	.208-03
CYANIDE	< .615-04	< .490-04
NITRATE	.738-05	< .525-05
SULFATE	.365-01	.266-01
AMMONIUM	< .615-04	< .490-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

3 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		.195-04		.149-04
ARSENIC		.252-03		.183-03
BARIUM		.893-02		.805-02
BERYLLIUM		.893-04		.557-05
BISMUTH		.106-04		.136-04
BORON	<	.812-02		.557-02
CADMIUM	<	.244-06		.712-06
CHROMIUM	<	.162-05	<	.124-05
COBALT	<	.122-06	<	.928-07
COPPER		.812-06		.102-05
IRON		.227-04		.371-04
LEAD	<	.365-06	<	.279-06
MANGANESE		.568-06		.526-06
MERCURY	<	.812-06	<	.279-06
MOLYBDENUM		.106-03		.743-04
NICKEL	<	.284-05	<	.217-05
SELENIUM	<	.406-05		.279-04
TELLURIUM	<	.203-05	<	.155-05
THALLIUM	<	.162-04	<	.124-04
TIN	<	.162-04	<	.124-04
TITANIUM	<	.406-04		.340-04
URANIUM	*	.000	*	.000
VANADIUM		.158-04		.130-04
ZINC		.406-06		.650-06
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	.771-04	*	.000
FLUORIDE	<	.406-06	*	.000
CYANIDE		.288-04	*	.000
NITRATE		.126-04	*	.000
SULFATE		.258-01	*	.000
AMMONIUM		.111-03	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION			
		BASELINE		LOW NOX
CATIONS				
ANTIMONY		.290-04		.850-05
ARSENIC		.203-03		.147-03
BARIUM		.638-03		.240-02
BERYLLIUM		.119-04		.471-04
BISMUTH		.392-05		.773-05
BORON	<	.290-02		.286-02
CADMIUM		.638-06		.773-06
CHROMIUM	<	.580-06	<	.386-06
COBALT	<	.435-07	<	.232-07
COPPER		.363-06		.402-06
IRON		.899-05		.147-04
LEAD	<	.131-06	<	.155-06
MANGANESE		.247-06		.209-06
MERCURY	<	.131-06	<	.695-07
MOLYBDENUM		.348-04		.355-04
NICKEL	<	.102-05	<	.618-06
SELENIUM		.305-04		.286-05
TELLURIUM	<	.725-06	<	.386-06
THALLIUM	<	.580-05	<	.309-05
TIN	<	.580-05	<	.309-05
TITANIUM		.160-04		.927-05
URANIUM	*	.000	*	.000
VANADIUM		.595-05		.348-05
ZINC		.305-06		.440-06
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

FILTER

TRACE ELEMENTS		TEST CONDITION		
		BASELINE		LOW NOX
CATIONS				
ANTIMONY		.610-04	<	.873-05
ARSENIC		.610-03		.388-03
BARIUM		.439-03		.100-01
BERYLLIUM		.780-07		.917-06
BISMUTH		.488-05	<	.873-05
BORON		.488-03	<	.873-03
CADMIUM		.200-04		.153-04
CHROMIUM	<	.146-06	<	.131-05
COBALT		.171-03		.100-03
COPPER		.561-03		.179-05
IRON	<	.975-08	<	.873-07
LEAD	<	.488-07	<	.436-06
MANGANESE		.244-04		.105-03
MERCURY		.146-06		.567-06
MOLYBDENUM		.610-04		.140-03
NICKEL		.268-03		.402-03
SELENIUM		.293-04		.279-04
TELLURIUM		.146-05	<	.262-05
THALLIUM		.317-05	<	.306-05
TIN		.171-04	<	.436-04
TITANIUM	<	.488-05		.349-04
URANIUM	*	.000	*	.000
VANADIUM		.341-03		.140-03
ZINC		.634-06		.205-05
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	.813-05	<	.901-05
ARSENIC	<	.813-05	<	.901-05
BARIUM	<	.651-06		.721-04
BERYLLIUM		.813-06		.451-06
BISMUTH	<	.651-05	<	.721-05
BORON	<	.163-01	<	.162-01
CADMIUM	<	.651-06	<	.721-06
CHROMIUM	<	.651-05		.451-04
COBALT	<	.488-06		.901-05
COPPER		.830-05	<	.541-07
IRON		.106-02		.342-03
LEAD		.586-05		.132-04
MANGANESE		.220-05		.270-05
MERCURY	<	.146-05		.132-04
MOLYBDENUM	<	.976-05	<	.108-04
NICKEL	<	.813-05	<	.901-05
SELENIUM	<	.813-05	<	.901-05
TELLURIUM	<	.813-05	<	.901-05
THALLIUM	<	.130-04	<	.901-05
TIN		.244-04	<	.126-04
TITANIUM		.325-03		.270-03
URANIUM	*	.000	*	.000
VANADIUM		.456-04		.451-04
ZINC		.130-05		.144-05
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	.491-06	<	.484-06
ARSENIC		.258-05		.403-05
BARIUM		.442-05		.951-04
BERYLLIUM		.491-07		.137-05
BISMUTH	<	.246-06		.984-05
BORON		.246-02		.435-02
CADMIUM		.123-05		.322-05
CHROMIUM	<	.246-06		.113-05
COBALT		.123-07		.484-07
COPPER		.614-08		.387-05
IRON		.344-04		.532-04
LEAD	<	.123-06	<	.161-06
MANGANESE		.614-07		.258-06
MERCURY	<	.123-06	<	.161-06
MOLYBDENUM		.270-04		.693-04
NICKEL		.417-03		.145-02
SELENIUM		.123-05		.903-05
TELLURIUM		.614-06	<	.484-06
THALLIUM		.123-05		.129-05
TIN		.160-04		.102-04
TITANIUM	<	.737-05	<	.967-05
URANIUM	*	.000	*	.000
VANADIUM		.859-06	<	.322-06
ZINC		.246-07		.451-06
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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                         SPREADER STOKER INDUSTRIAL BOILER
                TRACE ELEMENT ANALYSIS - (KG/MIN)-      BOILER OUTLET

                               2ND & 3RD IMPINGERS

TRACE ELEMENTS                    TEST CONDI!ION

CATIONS                            BASELINE           LOW NOX

  ANTIMONY                         .825-06        <   .157-05
  ARSENIC                      <   .144-05        <   .314-05
  BARIUM                       *   .000           *   .000
  BERYLLIUM                    *   .000           *   .000
  BISMUTH                      *   .000           *   .000

  BORON                        *   .000           *   .000
  CADMIUM                      *   .000           *   .000
  CHROMIUM                     *   .000           *   .000
  COBALT                       *   .000           *   .000
  COPPER                       *   .000           *   .000

  IRON                         *   .000           *   .000
  LEAD                         *   .000           *   .000
  MANGANESE                    *   .000           *   .000
  MERCURY                      <   .206-06            .680-05
  MOLYBDENUM                   *   .000           *   .000

  NICKEL                       *   .000           *   .000
  SELENIUM                     *   .000           *   .000
  TELLURIUM                    *   .000           *   .000
  THALLIUM                     *   .000           *   .000
  TIN                          *   .000           *   .000

  TITANIUM                     *   .000           *   .000
  URANIUM                      *   .000           *   .000
  VANADIUM                     *   .000           *   .000
  ZINC                         *   .000           *   .000
  ZIRCONIUM                    *   .000           *   .000

 ANIONS
  CHLORIDE                     *   .000           *   .000
  FLUORIDE                     *   .000           *   .000
  CYANIDE                      *   .000           *   .000
  NITRATE                      *   .000           *   .000
  SULFATE                      *   .000           *   .000

  AMMONIUM                     *   .000           *   .000
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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	< .134-03	.554-04
ARSENIC	.140-02	.944-03
BARIUM	.739-01	.105
BERYLLIUM	.148-02	.825-03
BISMUTH	.507-04	< .611-04
BORON	.114	< .474-01
CADMIUM	< .245-04	< .219-04
CHROMIUM	< .214-04	< .579-04
COBALT	< .172-03	< .110-03
COPPER	.574-03	.101-04
IRON	.152-02	.657-03
LEAD	< .114-04	< .177-04
MANGANESE	.317-04	.112-03
MERCURY	.780-05	< .226-04
MOLYBDENUM	.730-03	.662-03
NICKEL	< .717-03	< .188-02
SELENIUM	< .977-04	.180-03
TELLURIUM	< .277-04	< .245-04
THALLIUM	< .162-03	< .116-03
TIN	< .202-03	< .169-03
TITANIUM	< .615-03	< .516-03
URANIUM	* .000	* .000
VANADIUM	.528-03	.285-03
ZINC	.415-05	.608-05
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	< .566-03	< .388-03
FLUORIDE	.643-04	.208-03
CYANIDE	< .903-04	< .490-04
NITRATE	.200-04	< .525-05
SULFATE	.621-01	.266-01
AMMONIUM	< .173-03	< .490-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP HOPPER ASH

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		.686-04		.601-04
ARSENIC		.188-02		.114-02
BARIUM		.112-01		.543-02
BERYLLIUM		.196-03		.134-03
BISMUTH	<	.153-05		.213-04
BORON	<	.508-02		.523-02
CADMIUM		.254-05		.582-05
CHROMIUM	<	.102-05	<	.582-06
COBALT	<	.765-07	<	.388-07
COPPER		.158-05		.147-05
IRON		.765-04		.601-04
LEAD	<	.229-06	<	.174-06
MANGANESE		.534-06		.504-06
MERCURY		.508-06		.388-06
MOLYBDENUM		.534-04		.504-04
NICKEL	<	.178-05	<	.116-05
SELENIUM		.214-03		.233-03
TELLURIUM	<	.127-05	<	.775-06
THALLIUM	<	.102-04	<	.775-05
TIN		.839-04		.872-04
TITANIUM		.356-04		.165-04
URANIUM	*	.000	*	.000
VANADIUM		.117-04		.737-05
ZINC		.145-05		.159-05
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	.508-04	<	.386-04
FLUORIDE		.969-04		.121-03
CYANIDE	<	.381-06	<	.109-05
NITRATE		.458-05		.931-05
SULFATE		.280-01		.446-01
AMMONIUM		.458-06		.872-03

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                    SPREADER STOKER INDUSTRIAL BOILER
           TRACE ELEMENT ANALYSIS - (KG/MIN)-        ESP OUTLET

                         10 MICRON CYCLONE

TRACE ELEMENTS                  TEST CONDITION

CATIONS                           BASELINE          LOW NOX

  ANTIMONY                     *     .000         *     .000
  ARSENIC                      *     .000         *     .000
  BARIUM                       *     .000         *     .000
  BERYLLIUM                    *     .000         *     .000
  BISMUTH                      *     .000         *     .000

  BORON                        *     .000         *     .000
  CADMIUM                      *     .000         *     .000
  CHROMIUM                     *     .000         *     .000
  COBALT                       *     .000         *     .000
  COPPER                       *     .000         *     .000

  IRON                         *     .000         *     .000
  LEAD                         *     .000         *     .000
  MANGANESE                    *     .000         *     .000
  MERCURY                      *     .000         *     .000
  MOLYBDENUM                   *     .000         *     .000

  NICKEL                       *     .000         *     .000
  SELENIUM                     *     .000         *     .000
  TELLURIUM                    *     .000         *     .000
  THALLIUM                     *     .000         *     .000
  TIN                          *     .000         *     .000

  TITANIUM                     *     .000         *     .000
  URANIUM                      *     .000         *     .000
  VANADIUM                     *     .000         *     .000
  ZINC                         *     .000         *     .000
  ZIRCONIUM                    *     .000         *     .000

ANIONS
  CHLORIDE                     *     .000         *     .000
  FLUORIDE                     *     .000         *     .000
  CYANIDE                      *     .000         *     .000
  NITRATE                      *     .000         *     .000
  SULFATE                      *     .000         *     .000

  AMMONIUM                     *     .000         *     .000
```

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP OUTLET

3 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	*	.000	*	.000
ARSENIC	*	.000	*	.000
BARIUM	*	.000	*	.000
BERYLLIUM	*	.000	*	.000
BISMUTH	*	.000	*	.000
BORON	*	.000	*	.000
CADMIUM	*	.000	*	.000
CHROMIUM	*	.000	*	.000
COBALT	*	.000	*	.000
COPPER	*	.000	*	.000
IRON	*	.000	*	.000
LEAD	*	.000	*	.000
MANGANESE	*	.000	*	.000
MERCURY	*	.000	*	.000
MOLYBDENUM	*	.000	*	.000
NICKEL	*	.000	*	.000
SELENIUM	*	.000	*	.000
TELLURIUM	*	.000	*	.000
THALLIUM	*	.000	*	.000
TIN	*	.000	*	.000
TITANIUM	*	.000	*	.000
URANIUM	*	.000	*	.000
VANADIUM	*	.000	*	.000
ZINC	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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                    SPREADER STOKER INDUSTRIAL BOILER
         TRACE ELEMENT ANALYSIS - (KG/MIN)-        ESP OUTLET

                           1 MICRON CYCLONE

TRACE ELEMENTS                       TEST CONDITION

CATIONS                                BASELINE            LOW NOX

  ANTIMONY                         *     .000         *     .000
  ARSENIC                          *     .000         *     .000
  BARIUM                           *     .000         *     .000
  BERYLLIUM                        *     .000         *     .000
  BISMUTH                          *     .000         *     .000

  BORON                            *     .000         *     .000
  CADMIUM                          *     .000         *     .000
  CHROMIUM                         *     .000         *     .000
  COBALT                           *     .000         *     .000
  COPPER                           *     .000         *     .000

  IRON                             *     .000         *     .000
  LEAD                             *     .000         *     .000
  MANGANESE                        *     .000         *     .000
  MERCURY                          *     .000         *     .000
  MOLYBDENUM                       *     .000         *     .000

  NICKEL                           *     .000         *     .000
  SELENIUM                         *     .000         *     .000
  TELLURIUM                        *     .000         *     .000
  THALLIUM                         *     .000         *     .000
  TIN                              *     .000         *     .000

  TITANIUM                         *     .000         *     .000
  URANIUM                          *     .000         *     .000
  VANADIUM                         *     .000         *     .000
  ZINC                             *     .000         *     .000
  ZIRCONIUM                        *     .000         *     .000

ANIONS
  CHLORIDE                         *     .000         *     .000
  FLUORIDE                         *     .000         *     .000
  CYANIDE                          *     .000         *     .000
  NITRATE                          *     .000         *     .000
  SULFATE                          *     .000         *     .000

  AMMONIUM                         *     .000         *     .000
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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP OUTLET

FILTER

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		.213-05	<	.164-05
ARSENIC		.604-04		.534-04
BARIUM		.245-03	<	.247-07
BERYLLIUM		.142-06		.206-06
BISMUTH		.142-05		.206-05
BORON	<	.284-03		.148-02
CADMIUM		.676-06		.617-05
CHROMIUM		.149-05		.411-06
COBALT		.327-04		.366-05
COPPER		.818-04		.370-07
IRON		.110-05	<	.123-07
LEAD	<	.107-07	<	.822-07
MANGANESE		.640-05		.169-04
MERCURY		.427-07		.740-07
MOLYBDENUM		.107-04		.452-05
NICKEL		.818-04		.185-04
SELENIUM		.889-05		.411-05
TELLURIUM		.539-06	<	.411-06
THALLIUM		.142-06	<	.411-06
TIN		.889-05	<	.822-05
TITANIUM	<	.711-06	<	.370-05
URANIUM	*	.000	*	.000
VANADIUM		.391-04		.329-05
ZINC		.105-06	<	.822-08
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP OUTLET

XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	.388-05	<	.311-05
ARSENIC	<	.388-05	<	.311-05
BARIUM		.777-04	<	.248-06
BERYLLIUM		.171-05	<	.311-07
BISMUTH	<	.311-05	<	.248-05
BORON	<	.777-02	<	.559-02
CADMIUM	<	.311-06	<	.248-06
CHROMIUM		.109-03		.248-04
COBALT		.109-04		.522-05
COPPER		.427-04	<	.186-07
IRON		.474-03		.484-04
LEAD		.210-05	<	.559-06
MANGANESE		.163-04	<	.497-08
MERCURY		.396-05		.559-06
MOLYBDENUM	<	.388-05		.161-03
NICKEL		.482-04	<	.311-05
SELENIUM		.155-04		.137-04
TELLURIUM	<	.311-05		.342-05
THALLIUM	<	.311-05	<	.248-05
TIN	<	.544-05	<	.435-05
TITANIUM		.101-03		.683-04
URANIUM	*	.000	*	.000
VANADIUM		.186-03		.124-04
ZINC		.186-04	<	.497-07
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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                              SPREADER STOKER INDUSTRIAL BOILER
                      TRACE ELEMENT ANALYSIS - (KG/MIN)-         ESP OUTLET

                                       FIRST IMPINGERS

             TRACE ELEMENTS                     TEST CONDITION

             CATIONS                              BASELINE              LOW NOX

               ANTIMONY                        <     .328-06      <      .313-06
               ARSENIC                               .186-05             .334-05
               BARIUM                                .296-05             .397-05
               BERYLLIUM                             .427-06             .157-06
               BISMUTH                         <     .438-06      <      .418-06

               BORON                                 .515-02             .501-02
               CADMIUM                               .142-05             .167-05
               CHROMIUM                              .714-05             .564-05
               COBALT                                .142-06             .125-06
               COPPER                                .876-08             .209-07

               IRON                                  .712-04             .616-04
               LEAD                            <     .109-06      <      .104-06
               MANGANESE                             .777-06             .679-06
               MERCURY                               .547-06             .115-05
               MOLYBDENUM                            .602-03             .157-03

               NICKEL                                .499-02             .366-02
               SELENIUM                              .142-05             .178-05
               TELLURIUM                             .547-06             .836-06
               THALLIUM                        <     .547-06             .522-06
               TIN                                   .405-05      <      .104-05

               TITANIUM                        <     .547-05      <      .418-05
               URANIUM                         *     .000         *      .000
               VANADIUM                              .296-04             .125-04
               ZINC                                  .109-07             .313-07
               ZIRCONIUM                       *     .000         *      .000

             ANIONS
               CHLORIDE                        *     .000         *      .000
               FLUORIDE                        *     .000         *      .000
               CYANIDE                         *     .000         *      .000
               NITRATE                         *     .000         *      .000
               SULFATE                         *     .000         *      .000

               AMMONIUM                        *     .000         *      .000
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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP OUTLET

2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION			
	BASELINE		LOW NOX	
CATIONS				
ANTIMONY	<	.401-06	<	.347-06
ARSENIC	<	.702-06	<	.607-06
BARIUM	*	.000	*	.000
BERYLLIUM	*	.000	*	.000
BISMUTH	*	.000	*	.000
BORON	*	.000	*	.000
CADMIUM	*	.000	*	.000
CHROMIUM	*	.000	*	.000
COBALT	*	.000	*	.000
COPPER	*	.000	*	.000
IRON	*	.000	*	.000
LEAD	*	.000	*	.000
MANGANESE	*	.000	*	.000
MERCURY	<	.100-06		.260-06
MOLYBDENUM	*	.000	*	.000
NICKEL	*	.000	*	.000
SELENIUM	*	.000	*	.000
TELLURIUM	*	.000	*	.000
THALLIUM	*	.000	*	.000
TIN	*	.000	*	.000
TITANIUM	*	.000	*	.000
URANIUM	*	.000	*	.000
VANADIUM	*	.000	*	.000
ZINC	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP OUTLET

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		.675-05	<	.541-05
ARSENIC		.669-04		.605-04
BARIUM		.326-03	<	.424-05
BERYLLIUM		.228-05		.393-06
BISMUTH		.497-05		.496-05
BORON	<	.132-01		.121-01
CADMIUM		.142-01		.809-05
CHROMIUM		.117-03		.309-04
COBALT		.437-04		.900-05
COPPER		.125-03		.765-07
IRON		.546-03	<	.110-03
LEAD	<	.222-05	<	.746-06
MANGANESE		.235-04		.175-04
MERCURY		.465-05		.204-05
MOLYBDENUM		.617-03		.323-03
NICKEL		.506-02		.368-02
SELENIUM		.257-04		.195-04
TELLURIUM		.419-05	<	.466-05
THALLIUM		.380-05	<	.342-05
TIN		.184-04	<	.136-04
TITANIUM	<	.107-03	<	.762-04
URANIUM	*	.000	*	.000
VANADIUM		.255-03		.282-04
ZINC		.188-04	<	.892-07
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

APPENDIX D-2

TRACE ELEMENT FLOW RATES

(micrograms per joule)

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                         SPREADER STOKER INDUSTRIAL BOILER
                  TRACE ELEMENT ANALYSIS - (MCG/JOULE)-        FUEL INLET

TRACE ELEMENTS                        TEST CONDITION

CATIONS                                  BASELINE                LOW NOX

  ANTIMONY                         <     .660-05           <     .639-05
  ARSENIC                                .264-04                 .256-04
  BARIUM                                 .234-02                 .217-02
  BERYLLIUM                              .792-04                 .767-04
  BISMUTH                          <     .990-04           <     .958-04

  BORON                                  .660-03                 .160-03
  CADMIUM                          <     .330-05           <     .319-05
  CHROMIUM                               .429-03                 .415-03
  COBALT                                 .129-03                 .147-03
  COPPER                                 .561-03                 .511-03

  IRON                                   .124                    .961-01
  LEAD                             <     .165-03           <     .192-03
  MANGANESE                              .759-03                 .319-03
  MERCURY                                .132-05                 .160-05
  MOLYBDENUM                       <     .198-03           <     .224-03

  NICKEL                                 .307-03                 .297-03
  SELENIUM                               .52[illegible]-04                 .447-04
  TELLURIUM                        <     .660-05           <     .639-05
  THALLIUM                         <     .132-03           <     .160-03
  TIN                                    .264-04                 .192-04

  TITANIUM                               .363-01                 .361-01
  URANIUM                                .195-04                 .195-04
  VANADIUM                               .858-03                 .671-03
  ZINC                                   .284-03                 .351-03
  ZIRCONIUM                              .139-02                 .240-02

ANIONS
  CHLORIDE                         *     .000              *     .000
  FLUORIDE                         *     .000              *     .000
  CYANIDE                          *     .000              *     .000
  NITRATE                          *     .000              *     .000
  SULFATE                          *     .000              *     .000

  AMMONIUM                         *     .000              *     .000
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SPREADER STOKER INDUSTRIAL BOILER

TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOTTOM ASH

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	.713-06	<	.753-06
ARSENIC	<	.238-05	<	.251-05
BARIUM	<	.117-04	<	.125-04
BERYLLIUM	<	.238-06	<	.251-06
BISMUTH		.226-04		.238-04
BORON	<	.238-02	<	.251-02
CADMIUM		.997-06		.105-05
CHROMIUM		.131-03		.138-03
COBALT		.190-04		.201-04
COPPER		.114-03		.120-03
IRON		.238-01		.251-01
LEAD		.690-05		.728-05
MANGANESE		.547-03		.577-03
MERCURY	<	.832-06	<	.878-06
MOLYBDENUM	<	.357-05	<	.376-05
NICKEL		.571-04		.602-04
SELENIUM	<	.357-06	<	.376-06
TELLURIUM		.416-05		.439-05
THALLIUM	<	.357-05	<	.376-05
TIN		.250-03		.263-03
TITANIUM		.106-01		.112-01
URANIUM	*	.000	*	.000
VANADIUM		.226-03		.238-03
ZINC		.131-04		.138-04
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	.235-04	<	.248-04
FLUORIDE	<	.119-06	<	.125-06
CYANIDE	<	.297-05	<	.314-05
NITRATE		.321-05		.339-05
SULFATE		.427-03		.451-03
AMMONIUM		.108-04		.114-04

SAMPLE NOT TAKEN, ASSUMED SAME PPM AS LEA

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- MECHANICAL HOPPER ASH

TRACE ELEMENTS	TEST CONDITION			
		BASELINE		LOW NOX
CATIONS				
ANTIMONY	<	.161-05	<	.122-05
ARSENIC		.538-05	<	.406-05
BARIUM		.223-03		.752-03
BERYLLIUM		.646-04		.102-04
BISMUTH	<	.215-05	<	.203-05
BORON		.135-01	<	.406-02
CADMIUM	<	.807-07		.995-06
CHROMIUM		.242-01		.130-03
COBALT		.915-04	<	.203-06
COPPER		.124-03		.488-04
IRON		.377-01		.163-01
LEAD		.113-02		.140-04
MANGANESE		.834-03		.508-03
MERCURY	<	.242-06	<	.142-05
MOLYBDENUM	<	.135-05	<	.609-05
NICKEL		.108-03		.609-04
SELENIUM	<	.269-05	<	.609-06
TELLURIUM	<	.161-05		.102-05
THALLIUM	<	.135-04	<	.609-05
TIN		.538-03		.126-03
TITANIUM		.646-02		.284-02
URANIUM	*	.000	*	.000
VANADIUM		.145-03		.144-04
ZINC		.646-04		.447-04
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	.536-04	<	.406-04
FLUORIDE		.700-05		.126-04
CYANIDE	<	.673-05	<	.508-05
NITRATE	<	.807-06	<	.609-06
SULFATE		.333-02		.172-02
AMMONIUM	<	.673-05	<	.508-05

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                              SPREADER STOKER INDUSTRIAL BOILER
                   TRACE ELEMENT ANALYSIS - (MCG/JOULE)-       BOILER OUTLET

                                   10 MICRON CYCLONE

            TRACE ELEMENTS                  TEST CONDITION

            CATIONS                           BASELINE              LOW NOX

              ANTIMONY                  <      .335-05               .273-05
              ARSENIC                          .727-04               .468-04
              BARIUM                           .145-01               .187-01
              BERYLLIUM                        .313-03               .172-03
              BISMUTH                          .559-05         <     .312-05

              BORON                            .190-01         <     .390-02
              CADMIUM                   <      .391-06         <     .273-06
              CHROMIUM                  <      .279-05         <     .195-05
              COBALT                    <      .168-06         <     .117-06
              COPPER                           .894-06               .663-06

              IRON                             .894-04               .468-04
              LEAD                      <      .112-05         <     .780-06
              MANGANESE                        .950-06               .780-06
              MERCURY                          .112-05         <     .351-06
              MOLYBDENUM                       .112-03               .741-04

              NICKEL                    <      .447-05         <     .351-05
              SELENIUM                  <      .559-05               .230-04
              TELLURIUM                 <      .335-05         <     .234-05
              THALLIUM                  <      .279-04         <     .195-04
              TIN                       <      .279-04         <     .195-04

              TITANIUM                  <      .503-04         <     .351-04
              URANIUM                   *      .000            *     .000
              VANADIUM                         .268-04               .187-04
              ZINC                             .335-06               .234-06
              ZIRCONIUM                 *      .000            *     .000

            ANIONS
              CHLORIDE                  <      .111-03         <     .866-04
              FLUORIDE                         .145-04               .464-04
              CYANIDE                   <      .140-04         <     .109-04
              NITRATE                          .168-05         <     .117-05
              SULFATE                          .820-02               .594-02

              AMMONIUM                  <      .140-04         <     .109-04

INITIALIZATION FOR FILE   SPREADER STOKER INDUSTRIAL BOILER B
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                 SPREADER STOKER INDUSTRIAL BOILER
          TRACE ELEMENT ANALYSIS - (MCG/JOULE)-      BOILER OUTLET

                          3 MICRON CYCLONE

TRACE ELEMENTS                  TEST CONDITION

CATIONS                           BASELINE            LOW NOX

  ANTIMONY                         .443-05             .331-05
  ARSENIC                          .572-04             .407-04
  BARIUM                           .203-02             .179-02
  BERYLLIUM                        .203-04             .124-05
  BISMUTH                          .240-05             .304-05

  BORON                      <     .189-02             .124-02
  CADMIUM                    <     .554-07             .159-06
  CHROMIUM                   <     .369-06      <      .276-06
  COBALT                     <     .277-07      <      .207-07
  COPPER                           .185-06             .228-06

  IRON                             .517-05             .828-05
  LEAD                       <     .831-07      <      .621-07
  MANGANESE                        .129-06             .117-06
  MERCURY                    <     .185-06      <      .621-07
  MOLYBDENUM                       .240-04             .166-04

  NICKEL                     <     .646-06      <      .483-06
  SELENIUM                   <     .923-06             .621-05
  TELLURIUM                  <     .462-06      <      .345-06
  THALLIUM                   <     .369-05      <      .276-05
  TIN                        <     .369-05      <      .276-05

  TITANIUM                   <     .923-05             .759-05
  URANIUM                    *     .000         *      .000
  VANADIUM                         .360-05             .290-05
  ZINC                             .923-07             .145-06
  ZIRCONIUM                  *     .000         *      .000

ANIONS
  CHLORIDE                   <     .175-04      *      .000
  FLUORIDE                   <     .923-07      *      .000
  CYANIDE                          .655-05      *      .000
  NITRATE                          .286-05      *      .000
  SULFATE                          .586-02      *      .000

  AMMONIUM                         .253-04      *      .000
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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OUTLET

1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		.659-05		.190-05
ARSENIC		.462-04		.328-04
BARIUM		.145-03		.534-03
BERYLLIUM		.270-05		.105-04
BISMUTH		.890-06		.172-05
BORON	<	.659-03		.638-03
CADMIUM		.145-06		.172-06
CHROMIUM	<	.132-06	<	.862-07
COBALT	<	.989-08	<	.517-08
COPPER		.824-07		.896-07
IRON		.204-05		.328-05
LEAD	<	.297-07	<	.345-07
MANGANESE		.560-07		.465-07
MERCURY	<	.297-07	<	.155-07
MOLYBDENUM		.791-05		.793-05
NICKEL	<	.231-06	<	.138-06
SELENIUM		.692-05		.638-06
TELLURIUM	<	.165-06	<	.862-07
THALLIUM	<	.132-05	<	.690-06
TIN	<	.132-05	<	.690-06
TITANIUM		.363-05		.207-05
URANIUM	*	.000	*	.000
VANADIUM		.135-05		.776-06
ZINC		.692-07		.983-07
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OUTLET

FILTER

TRACE ELEMENTS	TEST CONDITION			
		BASELINE		LOW NOX
CATIONS				
ANTIMONY		.139-04	<	.195-05
ARSENIC		.139-03		.867-04
BARIUM		.998-04		.224-02
BERYLLIUM		.177-07		.204-06
BISMUTH		.111-05	<	.195-05
BORON		.111-03	<	.195-03
CADMIUM		.455-05		.341-05
CHROMIUM	<	.333-07	<	.292-06
COBALT		.388-04		.224-04
COPPER		.127-03		.399-06
IRON	<	.224-08	<	.195-07
LEAD	<	.111-07	<	.974-07
MANGANESE		.554-05		.234-04
MERCURY		.333-07		.127-06
MOLYBDENUM		.139-04		.312-04
NICKEL		.610-04		.896-04
SELENIUM		.665-05		.623-05
TELLURIUM		.333-06	<	.584-06
THALLIUM		.721-06	<	.682-06
TIN		.388-05	<	.974-05
TITANIUM	<	.111-05		.779-05
URANIUM	*	.000	*	.000
VANADIUM		.776-04		.312-04
ZINC		.144-06		.458-06
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OUTLET

XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION			
		BASELINE		LOW NOX
CATIONS				
ANTIMONY	<	.185-05	<	.201-05
ARSENIC	<	.185-05	<	.201-05
BARIUM	<	.148-06		.161-04
BERYLLIUM		.185-06		.101-06
BISMUTH	<	.148-05	<	.161-05
BORON	<	.370-02	<	.362-02
CADMIUM	<	.148-06	<	.161-06
CHROMIUM	<	.148-05		.101-04
COBALT	<	.111-06		.201-05
COPPER		.189-05	<	.121-07
IRON		.240-03		.764-04
LEAD		.133-05		.294-05
MANGANESE		.518-06		.603-06
MERCURY	<	.333-06		.294-05
MOLYBDENUM	<	.222-05	<	.241-05
NICKEL	<	.185-05	<	.201-05
SELENIUM	<	.185-05	<	.201-05
TELLURIUM	<	.185-05	<	.201-05
THALLIUM	<	.296-05	<	.201-05
TIN		.555-05	<	.281-05
TITANIUM		.740-04		.603-04
URANIUM	*	.000	*	.000
VANADIUM		.104-04		.101-04
ZINC		.296-06		.322-06
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OUTLET

FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	.112-06	<	.108-06
ARSENIC		.586-06		.899-06
BARIUM		.100-05		.212-04
BERYLLIUM		.112-07		.306-06
BISMUTH	<	.558-07		.219-05
BORON		.558-03		.971-03
CADMIUM		.279-06		.719-06
CHROMIUM	<	.558-07		.252-06
COBALT		.279-08		.108-07
COPPER		.140-08		.863-06
IRON		.781-05		.119-04
LEAD	<	.279-07	<	.360-07
MANGANESE		.140-07		.576-07
MERCURY	<	.279-07	<	.360-07
MOLYBDENUM		.614-05		.155-04
NICKEL		.949-04		.324-03
SELENIUM		.279-06		.201-05
TELLURIUM		.140-06	<	.108-06
THALLIUM		.279-06		.288-06
TIN		.363-05		.227-05
TITANIUM	<	.167-05	<	.216-05
URANIUM	*	.000	*	.000
VANADIUM		.195-06	<	.719-07
ZINC		.558-08		.101-06
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OUTLET

2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		.188-06	<	.350-06
ARSENIC	<	.328-06	<	.700-06
BARIUM	*	.000	*	.000
BERYLLIUM	*	.000	*	.000
BISMUTH	*	.000	*	.000
BORON	*	.000	*	.000
CADMIUM	*	.000	*	.000
CHROMIUM	*	.000	*	.000
COBALT	*	.000	*	.000
COPPER	*	.000	*	.000
IRON	*	.000	*	.000
LEAD	*	.000	*	.000
MANGANESE	*	.000	*	.000
MERCURY	<	.469-07		.152-05
MOLYBDENUM	*	.000	*	.000
NICKEL	*	.000	*	.000
SELENIUM	*	.000	*	.000
TELLURIUM	*	.000	*	.000
THALLIUM	*	.000	*	.000
TIN	*	.000	*	.000
TITANIUM	*	.000	*	.000
URANIUM	*	.000	*	.000
VANADIUM	*	.000	*	.000
ZINC	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OUTLET

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	.304-04		.124-04
ARSENIC		.317-03		.211-03
BARIUM		.168-01		.233-01
BERYLLIUM		.336-03		.184-03
BISMUTH		.115-04	<	.136-04
BORON		.257-01	<	.106-01
CADMIUM	<	.556-05	<	.489-05
CHROMIUM	<	.486-05	<	.129-04
COBALT	<	.391-04	<	.246-04
COPPER		.131-03		.226-05
IRON		.345-03		.147-03
LEAD	<	.260-05	<	.395-05
MANGANESE		.721-05		.250-04
MERCURY		.177-05	<	.504-05
MOLYBDENUM		.166-03		.148-03
NICKEL	<	.163-03	<	.419-03
SELENIUM	<	.222-04		.401-04
TELLURIUM	<	.630-05	<	.547-05
THALLIUM	<	.369-04	<	.259-04
TIN	<	.460-04	<	.378-04
TITANIUM	<	.140-03	<	.115-03
URANIUM	*	.000	*	.000
VANADIUM		.120-03		.637-04
ZINC		.945-06		.136-05
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	.127-03	<	.866-04
FLUORIDE		.146-04		.464-04
CYANIDE	<	.205-04	<	.109-04
NITRATE		.454-05	<	.117-05
SULFATE		.141-01		.594-02
AMMONIUM	<	.393-04	<	.109-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- ESP HOPPER ASH

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		.156-04		.134-04
ARSENIC		.427-03		.255-03
BARIUM		.254-02		.121-02
BERYLLIUM		.445-04		.298-04
BISMUTH	<	.346-06		.475-05
BORON	<	.115-02		.117-02
CADMIUM		.577-06		.130-05
CHROMIUM	<	.231-06	<	.130-06
COBALT	<	.173-07	<	.864-08
COPPER		.358-06		.328-06
IRON		.173-04		.134-04
LEAD	<	.520-07	<	.389-07
MANGANESE		.121-06		.112-06
MERCURY		.115-06		.864-07
MOLYBDENUM		.121-04		.112-04
NICKEL	<	.404-06	<	.259-06
SELENIUM		.485-04		.518-04
TELLURIUM	<	.289-06	<	.173-06
THALLIUM	<	.231-05	<	.173-05
TIN		.191-04		.194-04
TITANIUM		.808-05		.367-05
URANIUM	*	.000	*	.000
VANADIUM		.266-05		.164-05
ZINC		.329-06		.354-06
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	.115-04	<	.860-05
FLUORIDE		.220-04		.269-04
CYANIDE	<	.866-07	<	.242-06
NITRATE		.104-05		.207-05
SULFATE		.635-02		.994-02
AMMONIUM		.104-06		.194-03

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- ESP OUTLET

10 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	* .000	* .000
ARSENIC	* .000	* .000
BARIUM	* .000	* .000
BERYLLIUM	* .000	* .000
BISMUTH	* .000	* .000
BORON	* .000	* .000
CADMIUM	* .000	* .000
CHROMIUM	* .000	* .000
COBALT	* .000	* .000
COPPER	* .000	* .000
IRON	* .000	* .000
LEAD	* .000	* .000
MANGANESE	* .000	* .000
MERCURY	* .000	* .000
MOLYBDENUM	* .000	* .000
NICKEL	* .000	* .000
SELENIUM	* .000	* .000
TELLURIUM	* .000	* .000
THALLIUM	* .000	* .000
TIN	* .000	* .000
TITANIUM	* .000	* .000
URANIUM	* .000	* .000
VANADIUM	* .000	* .000
ZINC	* .000	* .000
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- ESP OUTLET

3 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	* .000	* .000
ARSENIC	* .000	* .000
BARIUM	* .000	* .000
BERYLLIUM	* .000	* .000
BISMUTH	* .000	* .000
BORON	* .000	* .000
CADMIUM	* .000	* .000
CHROMIUM	* .000	* .000
COBALT	* .000	* .000
COPPER	* .000	* .000
IRON	* .000	* .000
LEAD	* .000	* .000
MANGANESE	* .000	* .000
MERCURY	* .000	* .000
MOLYBDENUM	* .000	* .000
NICKEL	* .000	* .000
SELENIUM	* .000	* .000
TELLURIUM	* .000	* .000
THALLIUM	* .000	* .000
TIN	* .000	* .000
TITANIUM	* .000	* .000
URANIUM	* .000	* .000
VANADIUM	* .000	* .000
ZINC	* .000	* .000
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- ESP OUTLET

1 MICRON CYCLONE

TRACE ELEMENTS		TEST CONDITION		
CATIONS		BASELINE		LOW NOX
ANTIMONY	*	.000	*	.000
ARSENIC	*	.000	*	.000
BARIUM	*	.000	*	.000
BERYLLIUM	*	.000	*	.000
BISMUTH	*	.000	*	.000
BORON	*	.000	*	.000
CADMIUM	*	.000	*	.000
CHROMIUM	*	.000	*	.000
COBALT	*	.000	*	.000
COPPER	*	.000	*	.000
IRON	*	.000	*	.000
LEAD	*	.000	*	.000
MANGANESE	*	.000	*	.000
MERCURY	*	.000	*	.000
MOLYBDENUM	*	.000	*	.000
NICKEL	*	.000	*	.000
SELENIUM	*	.000	*	.000
TELLURIUM	*	.000	*	.000
THALLIUM	*	.000	*	.000
TIN	*	.000	*	.000
TITANIUM	*	.000	*	.000
URANIUM	*	.000	*	.000
VANADIUM	*	.000	*	.000
ZINC	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- ESP OUTLET

FILTER

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		.485-06	<	.367-06
ARSENIC		.137-04		.119-04
BARIUM		.558-04	<	.550-08
BERYLLIUM		.323-07		.459-07
BISMUTH		.323-06		.459-06
BORON	<	.647-04		.330-03
CADMIUM		.154-06		.138-05
CHROMIUM		.340-06		.917-07
COBALT		.744-05		.816-06
COPPER		.186-04		.825-08
IRON		.251-06	<	.275-08
LEAD	<	.243-08	<	.183-07
MANGANESE		.146-05		.376-05
MERCURY		.970-08		.165-07
MOLYBDENUM		.243-05		.101-05
NICKEL		.186-04		.413-05
SELENIUM		.202-05		.917-06
TELLURIUM		.121-06	<	.917-07
THALLIUM		.323-07	<	.917-07
TIN		.202-05	<	.183-05
TITANIUM	<	.162-06	<	.825-06
URANIUM	*	.000	*	.000
VANADIUM		.889-05		.734-06
ZINC		.234-07	<	.183-08
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- ESP OUTLET

XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	.883-06	<	.693-06
ARSENIC	<	.883-06	<	.693-06
BARIUM		.177-04	<	.554-07
BERYLLIUM		.389-06	<	.693-08
BISMUTH	<	.707-06	<	.554-06
BORON	<	.177-02	<	.125-02
CADMIUM	<	.707-07	<	.554-07
CHROMIUM		.247-04		.554-05
COBALT		.247-05		.116-05
COPPER		.972-05	<	.416-08
IRON		.108-03		.108-04
LEAD		.477-06	<	.125-06
MANGANESE		.371-05	<	.111-08
MERCURY		.901-06		.125-06
MOLYBDENUM	<	.883-06		.360-04
NICKEL		.110-04	<	.693-06
SELENIUM		.353-05		.305-05
TELLURIUM	<	.707-06		.762-06
THALLIUM	<	.707-06	<	.554-06
TIN	<	.124-05	<	.970-06
TITANIUM		.230-04		.152-04
URANIUM	*	.000	*	.000
VANADIUM		.424-04		.277-05
ZINC		.424-05	<	.111-07
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- ESP OUTLET

FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION BASELINE		LOW NOX	
CATIONS				
ANTIMONY	<	.747-07	<	.699-07
ARSENIC		.423-06		.746-06
BARIUM		.672-06		.885-06
BERYLLIUM		.971-07		.349-07
BISMUTH	<	.996-07	<	.932-07
BORON		.117-02		.112-02
CADMIUM		.324-06		.373-06
CHROMIUM		.162-05		.126-05
COBALT		.324-07		.280-07
COPPER		.199-08		.466-08
IRON		.162-04		.137-04
LEAD	<	.249-07	<	.233-07
MANGANESE		.177-06		.151-06
MERCURY		.124-06		.256-06
MOLYBDENUM		.137-03		.349-04
NICKEL		.112-02		.815-03
SELENIUM		.324-06		.396-06
TELLURIUM		.124-06		.186-06
THALLIUM	<	.124-06		.116-06
TIN		.921-06	<	.233-06
TITANIUM	<	.124-05	<	.932-06
URANIUM	*	.000	*	.000
VANADIUM		.672-05		.280-05
ZINC		.249-08		.699-08
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MLG/JOULE)- ESP OUTLET

2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	.912-07	<	.773-07
ARSENIC	<	.160-06	<	.135-06
BARIUM	*	.000	*	.000
BERYLLIUM	*	.000	*	.000
BISMUTH	*	.000	*	.000
BORON	*	.000	*	.000
CADMIUM	*	.000	*	.000
CHROMIUM	*	.000	*	.000
COBALT	*	.000	*	.000
COPPER	*	.000	*	.000
IRON	*	.000	*	.000
LEAD	*	.000	*	.000
MANGANESE	*	.000	*	.000
MERCURY	<	.228-07		.580-07
MOLYBDENUM	*	.000	*	.000
NICKEL	*	.000	*	.000
SELENIUM	*	.000	*	.000
TELLURIUM	*	.000	*	.000
THALLIUM	*	.000	*	.000
TIN	*	.000	*	.000
TITANIUM	*	.000	*	.000
URANIUM	*	.000	*	.000
VANADIUM	*	.000	*	.000
ZINC	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- ESP OUTLET

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		.153-05	<	.121-05
ARSENIC		.152-04		.135-04
BARIUM		.741-04	<	.946-06
BERYLLIUM		.518-06		.877-07
BISMUTH		.113-05		.111-05
BORON	<	.300-02		.270-02
CADMIUM		.324-02		.180-05
CHROMIUM		.267-04		.689-05
COBALT		.994-05		.201-05
COPPER		.283-04		.171-07
IRON		.124-03	<	.246-04
LEAD	<	.504-06	<	.166-06
MANGANESE		.534-05		.391-05
MERCURY		.106-05		.455-06
MOLYBDENUM		.140-03		.720-04
NICKEL		.115-02		.820-03
SELENIUM		.588-05		.436-05
TELLURIUM		.952-06	<	.104-05
THALLIUM		.863-06	<	.762-06
TIN		.418-05	<	.304-05
TITANIUM	<	.244-04	<	.170-04
URANIUM	*	.000	*	.000
VANADIUM		.580-04		.630-05
ZINC		.427-05	<	.199-07
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

APPENDIX D-3

TRACE ELEMENT FLOW RATES

(micrograms per dry standard cubic meter)

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

10 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	7.72		8.61
ARSENIC		167.		148.
BARIUM		.336+05		.590+05
BERYLLIUM		721.		541.
BISMUTH		12.9	<	9.84
BORON		.438+05	<	.123+05
CADMIUM	<	.901	<	.861
CHROMIUM	<	6.44	<	6.15
COBALT	<	.386	<	.369
COPPER		2.06		2.09
IRON		206.		148.
LEAD	<	2.57	<	2.46
MANGANESE		2.19		2.46
MERCURY		2.57	<	1.11
MOLYBDENUM		257.		234.
NICKEL	<	10.3	<	11.1
SELENIUM	<	12.9		72.6
TELLURIUM	<	7.72	<	7.38
THALLIUM	<	64.4	<	61.5
TIN	<	64.4	<	61.5
TITANIUM	<	116.	<	111.
URANIUM	*	.000	*	.000
VANADIUM		61.8		59.0
ZINC		.772		.738
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	256.	<	273.
FLUORIDE		33.5		146.
CYANIDE	<	32.2	<	34.4
NITRATE		3.86	<	3.69
SULFATE		.190+05		.187+05
AMMONIUM	<	32.2	<	34.4

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

3 MICRON CYCLONE

TRACE ELEMENTS		TEST CONDITION		
CATIONS		BASELINE		LOW NOX
ANTIMONY		10.2		10.4
ARSENIC		132.		128.
BARIUM		.468+04		.566+04
BERYLLIUM		46.0		3.92
BISMUTH		5.53		9.58
BORON	<	.425+04		.392+04
CADMIUM	<	.128		.501
CHROMIUM	<	.850	<	.871
COBALT	<	.638-01	<	.653-01
COPPER		.425		.718
IRON		11.9		26.1
LEAD	<	.191	<	.196
MANGANESE		.298		.370
MERCURY	<	.425	<	.196
MOLYBDENUM		55.5		52.2
NICKEL	<	1.49	<	1.52
SELENIUM	<	2.13		19.6
TELLURIUM	<	1.06	<	1.09
THALLIUM	<	8.50	<	8.71
TIN	<	8.50	<	8.71
TITANIUM	<	21.5		23.9
URANIUM	*	.000	*	.000
VANADIUM		8.29		9.14
ZINC		.213		.457
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	40.4	*	.000
FLUORIDE	<	.213	*	.000
CYANIDE		15.1	*	.000
NITRATE		6.59	*	.000
SULFATE		.135+05	*	.000
AMMONIUM		58.2	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	15.2	5.98
ARSENIC	106.	103.
BARIUM	334.	.168+04
BERYLLIUM	6.23	33.2
BISMUTH	2.05	5.43
BORON	< .152+04	.201+04
CADMIUM	.334	.543
CHROMIUM	< .304	< .272
COBALT	< .228-01	< .163-01
COPPER	.190	.283
IRON	4.71	10.3
LEAD	< .683-01	< .109
MANGANESE	.129	.147
MERCURY	< .683-01	< .489-01
MOLYBDENUM	18.2	25.0
NICKEL	< .531	< .435
SELENIUM	15.9	2.01
TELLURIUM	< .380	< .272
THALLIUM	< 3.04	< 2.17
TIN	< 3.04	< 2.17
TITANIUM	8.35	6.52
URANIUM	* .000	* .000
VANADIUM	3.11	2.45
ZINC	.159	.310
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

FILTER

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY		31.9	<	6.14
ARSENIC		319.		273.
BARIUM		230.		.706+04
BERYLLIUM		.408-01		.645
BISMUTH		2.55	<	6.14
BORON		255.	<	614.
CADMIUM		10.5		10.7
CHROMIUM	<	.766-01	<	.921
COBALT		89.4		70.6
COPPER		294.		1.26
IRON	<	.511-02	<	.614-01
LEAD	<	.255-01	<	.307
MANGANESE		12.8		73.7
MERCURY		.766-01		.399
MOLYBDENUM		31.9		98.2
NICKEL		140.		282.
SELENIUM		15.3		19.6
TELLURIUM		.766	<	1.84
THALLIUM		1.66	<	2.15
TIN		8.94	<	30.7
TITANIUM	<	2.55		24.6
URANIUM	*	.000	*	.000
VANADIUM		179.		98.2
ZINC		.332		1.44
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

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SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION			
	BASELINE		LOW NOX	
CATIONS				
ANTIMONY	<	4.26	<	6.34
ARSENIC	<	4.26	<	6.34
BARIUM	<	.341		50.7
BERYLLIUM		.426		.317
BISMUTH	<	3.41	<	5.07
BORON	<	.852+04	<	.114+05
CADMIUM	<	.341	<	.507
CHROMIUM	<	3.41		31.7
COBALT	<	.256		6.34
COPPER		4.34	<	.380-01
IRON		554.		241.
LEAD		3.07		9.25
MANGANESE		1.19		1.90
MERCURY	<	.767		9.25
MOLYBDENUM	<	5.11	<	7.61
NICKEL	<	4.26	<	6.34
SELENIUM	<	4.26	<	6.34
TELLURIUM	<	4.26	<	6.34
THALLIUM	<	6.81	<	6.34
TIN		12.0	<	8.87
TITANIUM		170.		190.
URANIUM	*	.000	*	.000
VANADIUM		23.9		31.7
ZINC		.681		1.01
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION			
CATIONS		BASELINE		LOW NOX
ANTIMONY	<	.257	<	.340
ARSENIC		1.35		2.83
BARIUM		2.31		66.9
BERYLLIUM		.257-01		.964
BISMUTH	<	.129		6.92
BORON		.127+04		.306+04
CADMIUM		.643		2.27
CHROMIUM	<	.129		.794
COBALT		.643-02		.340-01
COPPER		.321-02		2.72
IRON		18.0		37.4
LEAD	<	.643-01	<	.113
MANGANESE		.321-01		.181
MERCURY	<	.643-01	<	.113
MOLYBDENUM		14.1		40.8
NICKEL		219.		.102+04
SELENIUM		.643		6.35
TELLURIUM		.321	<	.340
THALLIUM		.643		.907
TIN		8.36		7.14
TITANIUM	<	3.86	<	6.80
URANIUM	*	.000	*	.000
VANADIUM		.450	<	.227
ZINC		.129-01		.318
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	.432	< 1.10
ARSENIC	< .756	< 2.21
BARIUM	* .000	* .000
BERYLLIUM	* .000	* .000
BISMUTH	* .000	* .000
BORON	* .000	* .000
CADMIUM	* .000	* .000
CHROMIUM	* .000	* .000
COBALT	* .000	* .000
COPPER	* .000	* .000
IRON	* .000	* .000
LEAD	* .000	* .000
MANGANESE	* .000	* .000
MERCURY	< .108	4.78
MOLYBDENUM	* .000	* .000
NICKEL	* .000	* .000
SELENIUM	* .000	* .000
TELLURIUM	* .000	* .000
THALLIUM	* .000	* .000
TIN	* .000	* .000
TITANIUM	* .000	* .000
URANIUM	* .000	* .000
VANADIUM	* .000	* .000
ZINC	* .000	* .000
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

TRACE ELEMENTS	TEST CONDITION			
		BASELINE		LOW NOX
CATIONS				
ANTIMONY	<	70.0		39.0
ARSENIC		731.		664.
BARIUM		.387+05		.735+05
BERYLLIUM		774.		580.
BISMUTH		26.5	<	43.0
BORON		.596+05	<	.333+05
CADMIUM	<	12.0	<	15.4
CHROMIUM	<	11.2	<	40.7
COBALT	<	90.1	<	77.4
COPPER		301.		7.11
IRON		794.		462.
LEAD	<	5.99	<	12.4
MANGANESE		16.[illegible]		78.7
MERCURY		4.08	<	15.9
MOLYBDENUM		382.		465.
NICKEL	<	376.	<	.132+04
SELENIUM	<	51.2		126.
TELLURIUM	<	14.5	<	17.3
THALLIUM	<	85.0	<	81.8
TIN	<	106.	<	119.
TITANIUM	<	322.	<	363.
URANIUM	*	.000	*	.000
VANADIUM		276.		201.
ZINC		2.17		4.28
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	<	297.	<	273.
FLUORIDE		33.7		146.
CYANIDE	<	47.3	<	34.4
NITRATE		10.5	<	3.69
SULFATE		.32[illegible]+05		.187+05
AMMONIUM	<	90.4	<	34.4

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                    SPREADER STOKER INDUSTRIAL BOILER
          TRACE ELEMENT ANALYSIS - (MCG/DSCM) -        ESP OUTLET

                          10 MICRON CYCLONE

TRACE ELEMENTS                        TEST CONDITION

CATIONS                                  BASELINE             LOW NOX

  ANTIMONY                            *     .000       *     .000
  ARSENIC                             *     .000       *     .000
  BARIUM                              *     .000       *     .000
  BERYLLIUM                           *     .000       *     .000
  BISMUTH                             *     .000       *     .000

  BORON                               *     .000       *     .000
  CADMIUM                             *     .000       *     .000
  CHROMIUM                            *     .000       *     .000
  COBALT                              *     .000       *     .000
  COPPER                              *     .000       *     .000

  IRON                                *     .000       *     .000
  LEAD                                *     .000       *     .000
  MANGANESE                           *     .000       *     .000
  MERCURY                             *     .000       *     .000
  MOLYBDENUM                          *     .000       *     .000

  NICKEL                              *     .000       *     .000
  SELENIUM                            *     .000       *     .000
  TELLURIUM                           *     .000       *     .000
  THALLIUM                            *     .000       *     .000
  TIN                                 *     .000       *     .000

  TITANIUM                            *     .000       *     .000
  URANIUM                             *     .000       *     .000
  VANADIUM                            *     .000       *     .000
  ZINC                                *     .000       *     .000
  ZIRCONIUM                           *     .000       *     .000

ANIONS
  CHLORIDE                            *     .000       *     .000
  FLUORIDE                            *     .000       *     .000
  CYANIDE                             *     .000       *     .000
  NITRATE                             *     .000       *     .000
  SULFATE                             *     .000       *     .000

  AMMONIUM                            *     .000       *     .000
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                        SPREADER STOKER INDUSTRIAL BOILER
              TRACE ELEMENT ANALYSIS - (MCG/DSCM) -        ESP OUTLET

                               3 MICRON CYCLONE

 TRACE ELEMENTS                     TEST CONDITION

'CATIONS                              BASELINE          LOW NOX

   ANTIMONY                        *     .000      *     .000
   ARSENIC                         *     .000      *     .000
   BARIUM                          *     .000      *     .000
   BERYLLIUM                       *     .000      *     .000
   BISMUTH                         *     .000      *     .000

   BORON                           *     .000      *     .000
   CADMIUM                         *     .000      *     .000
   CHROMIUM                        *     .000      *     .000
   COBALT                          *     .000      *     .000
   COPPER                          *     .000      *     .000

   IRON                            *     .000      *     .000
   LEAD                            *     .000      *     .000
   MANGANESE                       *     .000      *     .000
   MERCURY                         *     .000      *     .000
   MOLYBDENUM                      *     .000      *     .000

   NICKEL                          *     .000      *     .000
   SELENIUM                        *     .000      *     .000
   TELLURIUM                       *     .000      *     .000
   THALLIUM                        *     .000      *     .000
   TIN                             *     .000      *     .000

   TITANIUM                        *     .000      *     .000
   URANIUM                         *     .000      *     .000
   VANADIUM                        *     .000      *     .000
   ZINC                            *     .000      *     .000
   ZIRCONIUM                       *     .000      *     .000

 ANIONS
   CHLORIDE                        *     .000      *     .000
   FLUORIDE                        *     .000      *     .000
   CYANIDE                         *     .000      *     .000
   NITRATE                         *     .000      *     .000
   SULFATE                         *     .000      *     .000

   AMMONIUM                        *     .000      *     .000
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0.50

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                     SPREADER STOKER INDUSTRIAL BOILER
           TRACE ELEMENT ANALYSIS - (MCG/DSCM) -        ESP OUTLET

                             1 MICRON CYCLONE

TRACE ELEMENTS                       TEST CONDITION

CATIONS                                BASELINE           LOW NOX

  ANTIMONY                          *    .000        *    .000
  ARSENIC                           *    .000        *    .000
  BARIUM                            *    .000        *    .000
  BERYLLIUM                         *    .000        *    .000
  BISMUTH                           *    .000        *    .000

  BORON                             *    .000        *    .000
  CADMIUM                           *    .000        *    .000
  CHROMIUM                          *    .000        *    .000
  COBALT                            *    .000        *    .000
  COPPER                            *    .000        *    .000

  IRON                              *    .000        *    .000
  LEAD                              *    .000        *    .000
  MANGANESE                         *    .000        *    .000
  MERCURY                           *    .000        *    .000
  MOLYBDENUM                        *    .000        *    .000

  NICKEL                            *    .000        *    .000
  SELENIUM                          *    .000        *    .000
  TELLURIUM                         *    .000        *    .000
  THALLIUM                          *    .000        *    .000
  TIN                               *    .000        *    .000

  TITANIUM                          *    .000        *    .000
  URANIUM                           *    .000        *    .000
  VANADIUM                          *    .000        *    .000
  ZINC                              *    .000        *    .000
  ZIRCONIUM                         *    .000        *    .000

ANIONS
  CHLORIDE                          *    .000        *    .000
  FLUORIDE                          *    .000        *    .000
  CYANIDE                           *    .000        *    .000
  NITRATE                           *    .000        *    .000
  SULFATE                           *    .000        *    .000

  AMMONIUM                          *    .000        *    .000
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                      SPREADER STOKER INDUSTRIAL BOILER
             TRACE ELEMENT ANALYSIS - (MCG/DSCM) -        ESP OUTLET

                                  FILTER

TRACE ELEMENTS                TEST CONDITION

CATIONS                         BASELINE          LOW NOX

  ANTIMONY                        1.10        <    1.06
  ARSENIC                         31.2             34.6
  BARIUM                          127.        <    .160-01
  BERYLLIUM                       .735-01          .133
  BISMUTH                         .735             1.33

  BORON                     <     147.             957.
  CADMIUM                         .349             3.99
  CHROMIUM                        .772             .266
  COBALT                          16.9             2.37
  COPPER                          42.3             .239-01

  IRON                            .570        <    .798-02
  LEAD                      <     .551-02     <    .532-01
  MANGANESE                       3.31             10.9
  MERCURY                         .221-01          .479-01
  MOLYBDENUM                      5.51             2.92

  NICKEL                          42.3             12.0
  SELENIUM                        4.60             2.66
  TELLURIUM                       .276        <    .266
  THALLIUM                        .735-01     <    .266
  TIN                             4.60        <    5.32

  TITANIUM                  <     .368        <    2.39
  URANIUM                   *     .000        *    .000
  VANADIUM                        20.2             2.13
  ZINC                            .533-01     <    .532-02
  ZIRCONIUM                 *     .000        *    .000

ANIONS
  CHLORIDE                  *     .000        *    .000
  FLUORIDE                  *     .000        *    .000
  CYANIDE                   *     .000        *    .000
  NITRATE                   *     .000        *    .000
  SULFATE                   *     .000        *    .000

  AMMONIUM                  *     .000        *    .000
```

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - ESP OUTLET

XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION BASELINE	 LOW NOX
CATIONS		
ANTIMONY	< 2.01	< 2.01
ARSENIC	< 2.01	< 2.01
BARIUM	40.2	< .161
BERYLLIUM	.884	< .201-01
BISMUTH	< 1.61	< 1.61
BORON	< .402+04	< .361+04
CADMIUM	< .161	< .161
CHROMIUM	56.2	16.1
COBALT	5.62	3.37
COPPER	22.1	< .120-01
IRON	245.	31.3
LEAD	1.08	< .361
MANGANESE	8.44	< .321-02
MERCURY	2.05	.361
MOLYBDENUM	< 2.01	104.
NICKEL	24.9	< 2.01
SELENIUM	8.03	8.84
TELLURIUM	< 1.61	2.21
THALLIUM	< 1.61	< 1.61
TIN	< 2.81	< 2.81
TITANIUM	52.2	44.2
URANIUM	* .000	* .000
VANADIUM	96.4	8.03
ZINC	9.64	< .321-01
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

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                 SPREADER STOKER INDUSTRIAL BOILER
        TRACE ELEMENT ANALYSIS - (MCG/DSCM) -        ESP OUTLET

                          FIRST IMPINGERS

TRACE ELEMENTS                 TEST CONDITION

CATIONS                           BASELINE          LOW NOX

  ANTIMONY                   <     .170       <     .203
  ARSENIC                          .962             2.16
  BARIUM                           1.53             2.57
  BERYLLIUM                        .221             .101
  BISMUTH                    <     .226       <     .270

  BORON                            .266+04          .324+04
  CADMIUM                          .736+00          1.08
  CHROMIUM                         3.68             3.65
  COBALT                           .736-01          .811-01
  COPPER                           .453-02          .135-01

  IRON                             36.8             39.9
  LEAD                       <     .566-01    <     .675-01
  MANGANESE                        .402             .439
  MERCURY                          .283             .743
  MOLYBDENUM                       311.             101.

  NICKEL                           .255+04          .236+04
  SELENIUM                         .736             1.15
  TELLURIUM                        .283             .540
  THALLIUM                   <     .283             .338
  TIN                              2.09       <     .675

  TITANIUM                   <     2.83       <     2.70
  URANIUM                    *     .000       *     .000
  VANADIUM                         15.3             8.11
  ZINC                             .566-02          .203-01
  ZIRCONIUM                  *     .000       *     .000

ANIONS
  CHLORIDE                   *     .000       *     .000
  FLUORIDE                   *     .000       *     .000
  CYANIDE                    *     .000       *     .000
  NITRATE                    *     .000       *     .000
  SULFATE                    *     .000       *     .000

  AMMONIUM                   *     .000       *     .000
```

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - ESP OUTLET

2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION			
	BASELINE		LOW NOX	
CATIONS				
ANTIMONY	<	.207	<	.224
ARSENIC	<	.363	<	.392
BARIUM	*	.000	*	.000
BERYLLIUM	*	.000	*	.000
BISMUTH	*	.000	*	.000
BORON	*	.000	*	.000
CADMIUM	*	.000	*	.000
CHROMIUM	*	.000	*	.000
COBALT	*	.000	*	.000
COPPER	*	.000	*	.000
IRON	*	.000	*	.000
LEAD	*	.000	*	.000
MANGANESE	*	.000	*	.000
MERCURY	<	.519-01		.168
MOLYBDENUM	*	.000	*	.000
NICKEL	*	.000	*	.000
SELENIUM	*	.000	*	.000
TELLURIUM	*	.000	*	.000
THALLIUM	*	.000	*	.000
TIN	*	.000	*	.000
TITANIUM	*	.000	*	.000
URANIUM	*	.000	*	.000
VANADIUM	*	.000	*	.000
ZINC	*	.000	*	.000
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - ESP OUTLET

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	3.49	< 3.50
ARSENIC	34.6	39.1
BARIUM	169.	< 2.74
BERYLLIUM	1.18	.254
BISMUTH	2.57	3.21
BORON	< .682+04	.781+04
CADMIUM	< 1.25	5.23
CHROMIUM	60.7	20.0
COBALT	22.6	5.82
COPPER	64.4	.495-01
IRON	282.	< 71.2
LEAD	< 1.15	< .482
MANGANESE	12.1	11.3
MERCURY	2.41	1.32
MOLYBDENUM	319.	209.
NICKEL	.261+04	.238+04
SELENIUM	13.4	12.6
TELLURIUM	2.17	< 3.02
THALLIUM	1.96	< 2.21
TIN	9.50	< 8.80
TITANIUM	< 55.4	< 49.3
URANIUM	* .000	* .000
VANADIUM	132.	18.3
ZINC	9.70	< .577-01
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

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APPENDIX E

INFRARED SPECTRA

TABLE E-1. INFRARED SPECTRA OF TOTAL EXTRACTS

Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA - Bottom Ash			
3600-3150	M	hydroxyl	
3050	W	aromatic CH	
2950, 2920, 2850	S	aliphatic CH	
1740	M	carbonyl	broad
1600	M	aromatic C=C	broad
1460, 1375	S	methyl	
1290-1260	M	ester	
740	M	unassigned	
Baseline - Mechanical Hopper Ash			
2960, 2850	S	aliphatic CH	
1460	W	methyl bending	
LEA - Mechanical Hopper Ash			
2920, 2850	S	aliphatic CH	
1430	W	methyl bending	

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TABLE E-1. Continued

Wave Number (cm^{-1})	Intensity	Assignment	Comments
Baseline - ESP Hopper Ash			
3700-3000	VS	hydroxyl	
2950, 2920, 2850	M	aliphatic C-H	
1730	M	carbonyl	
LEA - ESP Hopper Ash			
2920, 2850	S	aliphatic CH	
1730	W	carbonyl	
1430	W	methyl bending	
1260	M	unassigned C-O	
Baseline - SASS - 10μ + 3μ Cyclones, Boiler Outlet			
2920, 2850	"S"	aliphatic CH	
LEA - SASS - 10μ + 3μ Cyclones, Boiler Outlet			
2950, 2920, 2850	"S"	aliphatic CH	
1725	M	carbonyl	

TABLE E-1. Continued

Wave Number (cm^{-1})	Intensity	Assignment	Comments
Baseline - SASS - XAD-2 + Condensate, ESP Outlet			
2960, 2920, 2850	S	aliphatic CH	
3020, 3060	W	aromatic CH	
3600, 2900	M	hydroxyl	broad
1710	S	carbonyl	broad
1600	S	aromatic double bond	very strong for this vibration
1570	M	unassigned	
1490	M	unassigned	
1450-1440, 1370	S	methyl bending	
1265	S	ester	
735, 700	M	unassigned	
LEA - SASS - XAD-2 + Condensate, ESP Outlet			
3140-3700	M	hydroxyl	broad
3040, 3030, 3010	W	aromatic C-H	
2850, 2960, 2920	S	aliphatic C-H	
1700-1720	S	carbonyl	broad
1600	W	aromatic double bond	
1490	W	unassigned	
1450, 1380	M	methyl bending	

TABLE E-1. Concluded

Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA - SASS - XAD-2 + Condensate, ESP Outlet			
1260	S	C-O stretching	
1090	M	unassigned	
1020	M	unassigned	
800	S	substitution patterns on	
695	M	double bond or aromatic ring	
LEA - SASS - XAD-2 + Condensate, Boiler Outlet			
3600-3150	M	hydroxyl	
3030, 3010	W	aromatic CH	
2950, 2920, 2850	S	aliphatic CH	
1740, 1730	M	broad carbonyl	
1600	W	aromatic double bond	
1490	M	unassigned	
1450	M	methyl bending	
750	M	unassigned	
695	S	unassigned	

TABLE E-2. INFRARED ANALYSES OF LIQUID CHROMATOGRAPHS FRACTIONS

Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA - Bottom Ash - LC Fraction 1			
2950, 2920, 2850	S	aliphatic C-H	
1460, 1370	M	methyl/aliphatic bending	
LEA - Bottom Ash - LC Fraction 2			
2950, 2920, 2850	S	aliphatic CH	
1450, 1380	M	methyl bending	
LEA -Bottom Ash - LC Fraction 3			
3100-300	W	aromatic CH	undefined
2960, 2920, 2850	S	aliphatic CH	
1600	M	aromatic C=C	broad
1450, 1370	M	methyl bending	
810	M	unassigned	
740	M	unassigned	
LEA - Bottom Ash - LC Fraction 4			
2960, 2920, 2860	S	aliphatic CH	
1450, 1370	M	methyl/aliphatic bending	

TABLE E-2. Continued

Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA - Bottom Ash - LC Fraction 5			
2950, 2920, 2850	S	aliphatic CH	
LEA - Bottom Ash - LC Fraction 6			
2960, 2920, 2850	S	aliphatic C-H	
LEA - Bottom Ash - LC Fraction 7			
3600-3100	M	hydroxyl	broad
2950, 2920, 2850	S	aliphatic C-H	
1750-1650	S	carbonyl	broad
1650-1550	S	unassigned may include aromatic C=C	
1450, 1370	M	methyl bending	
1280	M	possible C-O stretch	broad
LEA - Boiler Outlet, XAD-2 - Condensate Extracts, LC Fraction 1			
2950, 2920, 2850	S	aliphatic C-H	
1460, 1370	M	methyl/aliphatic bending	

TABLE E-2. Continued

Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA - Boiler Outlet, XAD-2 - Condensate Extracts, LC Fraction 2			
2950, 2920, 2850	S	aliphatic CH	
1460, 1370	M	methyl/aliphatic bending	
LEA - Boiler Outlet, XAD-2 - Condensate Extracts, LC Fraction 3			
2960, 2920, 2850	S	aliphatic C-H	
LEA - Boiler Outlet, XAD-2 - Condensate Extracts, LC Fraction 4			
3080, 3060, 3020	W	aromatic CH	
2950, 2920, 2840	S	aliphatic CH	
1730	M	carbonyl	
1600, 1490	W	aromatic C=C	
1450		methyl/aliphatic bending	
1260-1290	M	C-O (ester?)	broad
1120	W	unassigned	
1065	W	unassigned	
1025	W	unassigned	
750	M	may be solvent related	broad

TABLE E-2. Continued

Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA - Boiler Outlet, XAD-2 - Condensate Extracts, LC Fraction 5			
3080, 3060, 3020	M	aromatic CH	
2950, 2920, 2850	S	aliphatic CH	
1735	M	carbonyl	
1600, 1490	M	aromatic C=C	
1450	M	methyl/aliphatic bending	
750	M	broad unassigned	
695	S	solvent related probably C-Cl	
LEA - Boiler Outlet, XAD-2 - Condensate Extracts, LC Fraction 6			
3600-3100	W	hydroxyl	
3080, 3060, 3020	W	aromatic CH	
2950, 2920, 2850	S	aliphatic CH	
1740	S	carbonyl	broad
1600, 1490	M	aromatic C=C	
1450, 1370	M	methyl/aliphatic bending	
1240	M	C-O	very broad
750	M	aromatic substitution bond?	
700	S	C-Cl	

TABLE E-2. Continued

Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA - Boiler Outlet, XAD-2 - Condensate Extracts, LC Fraction 7			
3650-2500	S	hydroxyl	broad
3060, 3020	W	aromatic CH	
2960, 2920, 2870			
2850	S	aliphatic CH	
1735	S	carbonyl	broad
1600, 1490	W	aromatic C=C	
1450, 1370	M	methyl bending	
1230-1270	S	C-O stretching	very broad
1120	W	unassigned	
1070	W	unassigned	
930	W	unassigned	
750	M	unassigned	
700	M	unassigned - possibly C-Cl from solvent	
LEA, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 1			
2950, 2920, 2860			
2850	S	aliphatic CH	
1450, 1370	M	methyl/aliphatic bending	

TABLE E-2. Continued

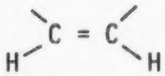
Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 2			
2950, 2920, 2850	W	aliphatic CH	
LEA, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 3			
2960	W	aliphatic CH	
1260	M	possible ether bond	
1090	M	unassigned	
1030	S	possible ether bond	
860	W	unassigned	
800	M	unassigned	
LEA, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 4			
3080, 3060, 3020			
3000	M	aromatic CH	
2950, 2920, 2850	S	aliphatic CH	
2000-1750	W	aromatic combination bonds	
1730	M	carbonyl	broad
1600, 1495	M	aromatic 	
1450, 1370	M	methyl/aliphatic bending	
1260	M	possible ether	

TABLE E-2. Continued

Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 4			
1080	M	unassigned	
1020	M	possible ether	
800	M	unassigned	
750, 700	M	unassigned, present in blank salt plate	
LEA, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 5			
3080, 3060, 3020	M	aromatic CH	
2960, 2920, 2850	S	aliphatic CH	
1725	S	carbonyl	
1600	M	aromatic C=C	
1490	M	skeletal in plane	
1450, 1370	M	methyl/aliphatic bending	
1260-1280	M	ester C-O stretch?	broad
1120-1000	M	Three unassigned bonds	broad
800	W	unassigned	
750, 700	M	unassigned, present in blank salt plate	

TABLE E-2. Continued

Wave Number (cm^{-1})	Intensity	Assignment	Comments
LEA, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 6			
3700-2400	S	hydroxyl	
3060, 3020	W	aromatic CH	
2960, 2920, 2840	S	aliphatic CH	
1725-1700	S	carbonyl	broad
1600, 1490	W	aromatic C=C	
1450, 1370	W	methyl/aliphatic bending	
1290-1260	S	C-O	broad
1020	M	unassigned	
970	M	unassigned	
920	M	unassigned	
800	M	unassigned	
750	W	unassigned	
710	M	unassigned, present in blank	
LEA, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 7			
3700-2400	S	hydroxyl	
2960, 2920, 2850	M	aliphatic CH	
1710-1730	S	carbonyl	very broad
1260	M	C-O	very broad
800	W	unassigned	

TABLE E-2. Continued

Wave Number (cm^{-1})	Intensity	Assignment	Comments
Baseline, ESP Outlet, XAD-2 Extract, Condensate Extracts, LC Fraction 1			
2950, 2920, 2850	S	aliphatic C-H	
1460, 1375	W	methyl bending	
Baseline, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 2			
2950, 2920, 2850	S	aliphatic CH	
1270	W	unassigned	Both possibly due to instrument
750	S	unassigned	
Baseline, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 3			
2960, 2920, 2850	S	aliphatic C-H	
Baseline, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 4			
3090, 3060, 3020	M	aromatic CH	
2920, 2850	S	aliphatic CH	
1600, 1490	M	aromatic C=C	
1450	M	methyl bending	
750	M	unassigned probably aromatic substitute	
695	S	unassigned probably C-Cl	

TABLE E-2. Continued

Wave Number (cm-1)	Intensity	Assignment	Comments
Baseline, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 5			
3080, 3060, 3020	M	aromatic CH	
2920, 2850	S	aliphatic CH	
1725	M	carbonyl	broad
1600, 1490	M	aromatic C=C	
1450	M	methyl bonded	
1270	W	C-O stretch	
750	S	unassigned (aromatic sub)	
695	VS	unassigned (C-Cl)	
Baseline, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 6			
3600-3100	M	hydroxyl	broad
3060, 3020	W	aromatic CH	
2960, 2920, 2860	S	aliphatic CH	
1720-1730	S	carbonyl	broad
1600, 1490	W	aromatic C=C	
1450	M	Methyl/aliphatic bending	
1280	M	C-O stretch	broad
750	W	unassigned	
695	M	unassigned probably C-Cl	

TABLE E-2. Concluded

Wave Number (cm-1)	Intensity	Assignment	Comments
Baseline, ESP Outlet, XAD-2, Condensate Extracts, LC Fraction 7			
3700-2400	S	hydroxyl	broad
3080, 3060	W	aromatic CH	
2960, 2920, 2870	M	aliphatic CH	
1700	VS	carbonyl	
1600, 1490	W	aromatic C=C	
1580	W	unassigned	
1450, 1370	M	methyl bending	
1410	W	unassigned	
1315	W	unassigned	
1250-1280	S	C-O stretching	
1170	W	unassigned	
1120	M	unassigned	
1070	W	unassigned	
1020	W	unassigned	
710	M	unassigned probably C-Cl	

APPENDIX F

BIOASSAY RESULTS

MUTAGENICITY EVALUATION OF
STOKER FIRED BOILER #2
BOILER BOTTOM ASH
IN THE
AMES SALMONELLA/MICROSOME PLATE TEST

FINAL REPORT

SUBMITTED TO:

ACUREX CORPORATION
485 CLYDE AVENUE
MOUNTAIN VIEW, CALIFORNIA 94042

SUBMITTED BY:

LITTON BIONETICS, INC.
5516 NICHOLSON LANE
KENSINGTON, MARYLAND 20795

LBI PROJECT NO. 20988

OCTOBER 1978

Litton BIONETICS

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I. SPONSOR: Acurex Corporation

II. MATERIAL*

A. Identification: Stoker Fired Boiler #2, Boiler Bottom Ash

B. Date Received: July 20, 1978

C. Physical Description: Solid in form of a conglomerate mixture

III. TYPE OF ASSAY: Ames *Salmonella*/Microsome Plate Test

IV. PROTOCOL NO.: DMT-100

V. RESULTS

The results of this assay are presented in Tables 1 and 2.

VI. INTERPRETATION OF RESULTS AND CONCLUSIONS

The test compound was examined for mutagenic activity in a series of *in vitro* microbial assays employing *Salmonella* indicator organisms. The compound was tested directly and in the presence of liver microsomal enzyme preparations from Aroclor-induced rats. The following results were obtained:

The compound was tested over a series of concentrations for toxicity as well as for mutagenesis assays. The dose range employed for the evaluation of this compound was from 0.01 mg to 10 mg per plate.

The test compound did not exhibit toxicity with any of the strains at the doses tested.

The results of the tests conducted on the compound in the absence of a metabolic activation system were all negative.

The results of the tests conducted on the compound in the presence of a rat liver activation system were all negative.

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*Information was supplied by the sponsor. If the sponsor did not indicate this information, N.I. was entered.

VI. INTERPRETATION OF RESULTS AND CONCLUSIONS (Continued)

The test compound Stoker Fired Boiler #2 Boiler Bottom Ash did not demonstrate genetic activity nor was it toxic to the bacterial indicator strains at the doses employed in any of the assays conducted in this evaluation. These results indicate that the compound is neither mutagenic nor toxic at these doses under these test conditions.

Submitted by:

Study Director

for Kulbir S. Bakshi 10/25/78
D.R. Jagannath, Ph.D. Date
Section Chief
Submammalian Genetics
Department of Genetics
and Cell Biology

Reviewed by:

10/30/78
David J. Brusick, Ph.D. Date
Director
Department of Genetics
and Cell Biology

ACUTE ORAL TOXICITY STUDY
IN THE RAT

STOKER-FIRED BOILER NO. 2 - ELECTROSTATIC PRECIPITATOR ASH

FINAL REPORT

SUBMITTED TO:

ACUREX CORPORATION
485 CLYDE AVENUE
MOUNTAIN VIEW, CALIFORNIA 94042

SUBMITTED BY:

LITTON BIONETICS, INC.
5516 NICHOLSON LANE
KENSINGTON, MARYLAND 20795

LBI PROJECT NO. 21010 (1-B)

JANUARY 1979

Litton BIONETICS

SPONSOR: Acurex Corporation

MATERIAL: Stoker-Fired Boiler No. 2 - Electrostatic Precipitator Ash

SUBJECT: FINAL REPORT
Acute Oral Toxicity Study in the Rat
LBI Project No. 21010 (1-B)

SUMMARY

The oral LD50 value of the test material was greater than 10,000 mg/kg for both male and female rats.

LBI ASSAY NO. 3509

CYTOTOXIC EVALUATION OF

STOKER FIRED BOILER #2
ELECTROSTATIC PRECIPITATOR HOPPER ASH

IN THE
RABBIT ALVEOLAR MACROPHAGE (RAM)
CYTOTOXICITY ASSAY

FINAL REPORT

SUBMITTED TO:

ACUREX CORPORATION
485 CLYDE AVE.
MOUNTAIN VIEW, CALIF. 94092

SUBMITTED BY:

LITTON BIONETICS, INC.
5516 NICHOLSON LANE
KENSINGTON, MARYLAND 20795

LBI PROJECT NO. 20993

REPORT DATE: FEBRUARY 1979

Litton BIONETICS

I. SPONSOR: Acurex Corporation

II. MATERIAL (TEST COMPOUND): LBI ASSAY NUMBER #3509

A. Identification: Stoker Fired Boiler #2 Electrostatic Precipitator Hopper Ash

B. Date Received: July 20, 1978

C. Physical Description: Fine black powder

III. TYPE OF ASSAY: Rabbit Alveolar Macrophage Cytotoxicity Assay

IV. PROTOCOL NUMBER: 443

V. STUDY DATES:

A. Initiation: February 1, 1979

B. Completion: February 6, 1979

VI. SUPERVISORY PERSONNEL:

A. Study Director: Brian Myhr, Ph.D.

B. Laboratory Supervisor: Robert Young

VII. RESULTS:

The data are presented in Table 1 on page 3 and in Figures 1 and 2 on pages 4 and 5.

VIII. INTERPRETATION OF RESULTS:

About 24 mg of test material was placed into 0.1 ml DMSO and sonicated. After sitting for 2-3 hours to sterilize and leach the material, the suspension was diluted into growth medium and applied to the cell cultures at a maximum concentration of 1000 μg/ml. The maximum DMSO concentration was 0.42%; this decreased with successive dilutions in growth medium. The negative control cultures did not contain DMSO.

Four of the five assay parameters yielded EC50 values in the 100 μg/ml to 1000 μg/ml concentration range. The fifth parameter, cellular protein, was the least responsive and gave an EC50 value greater than 1000 μg/ml. The most sensitive parameter was the culture ATP content (EC50 = 330 μg/ml). When the ATP content is expressed as the amount per 10^6 cells in the culture, the EC50 increases; this occurred because the cell number decreased with increasing test concentrations and the ATP released into the growth medium contributes to the ATP assay. The ATP content, ATP/10^6 cells, and viability index gave very similar EC50 values which clearly place the test material in the low toxicity classification.

IX. CONCLUSION:

The test material, Stoker Fired Boiler #2, Electrostatic Precipitator Hopper Ash, is evaluated as having low toxicity in the Rabbit Alveolar Macrophage Cytotoxicity Assay. The most sensitive assay parameter was ATP content, which gave an EC50 value of 330 µg/ml.

Submitted by:

Study Director

Brian Myhr 2/26/79
Brian Myhr, Ph.D. **date**
Section Chief
Mammalian Genetics
Department of Genetics
and Cell Biology

Reviewed by:

2/26/79
David J. Brusick, Ph.D. **date**
Director
Department of Genetics
and Cell Biology

Litton **BIONETICS**

UCES Proj. No. 11507-03-01

THE ACUTE TOXICITY OF
STOKER FIRED BOILER NO. 2 BOILER BOTTOM ASH
TO THE
FATHEAD MINNOW *Pimephales promelas* Rafinesque

Prepared For

Acurex Corporation
Mountain View, CA

Prepared By

UNION CARBIDE ENVIRONMENTAL SERVICES
Union Carbide Corporation
Tarrytown, New York 10591

September 22, 1978

UNION CARBIDE CORPORATION
ENVIRONMENTAL SERVICES
TARRYTOWN TECHNICAL CENTER
TARRYTOWN, NEW YORK 10591 • PHONE: (914) 345-3974

Client:	Acurex Corporation
Date:	The test was conducted from August 29 through September 2, 1978.
Material:	Stoker Fired Boiler No. 2, Boiler Bottom Ash
UCES Proj. No.:	11507-03-01
Summary:	The 96 hour LC_{50} for Stoker Fired Boiler No. 2, Boiler Bottom Ash to fathead minnows is greater than 1,000.0 mg/l. This value is based upon nominal concentrations of the chemical in soft reconstituted water.
Species:	Fathead minnow
Length:	57 mm
Weight:	2.02 grams
Source:	UCES Laboratory
96 Hour LC_{50}:	>1,000.0 mg/l
95% Conf. Limits:	Not available
96 Hour Observed No Effect Level:	1,000.0 mg/l
Water Quality:	Soft
Temperature:	21.8°C ± 0.3°C
pH:	7.45
Total Hardness as $CaCO_3$:	44 mg/l
Notebook Ref.:	No. 5169, pages 1, 2

LBI ASSAY NO. 3510

CYTOTOXIC EVALUATION OF

STOKER FIRED BOILER #2
BOILER BOTTOM ASH

IN THE
RABBIT ALVEOLAR MACROPHAGE (RAM) CYTOTOXICITY ASSAY

FINAL REPORT

SUBMITTED TO:

ACUREX CORPORATION
485 CLYDE AVE.
MOUNTAIN VIEW, CALIF. 94092

SUBMITTED BY:

LITTON BIONETICS, INC.
5516 NICHOLSON LANE
KENSINGTON, MARYLAND 20795

LBI PROJECT NO. 20993

REPORT DATE: FEBRUARY 1979

Litton BIONETICS

I. SPONSOR: Acurex Corporation

II. MATERIAL (TEST COMPOUND): LBI ASSAY NUMBER #3510

A. Identification: Stoker Fired Boiler #2 Boiler Bottom Ash

B. Date Received: July 20, 1978

C. Physical Description: Coarse multi-colored particles

III. TYPE OF ASSAY: Rabbit Alveolar Macrophage Cytotoxicity Assay

IV. PROTOCOL NUMBER: 443

V. STUDY DATES:

A. Initiation: February 8, 1979

B. Completion: February 9, 1979

VI. SUPERVISORY PERSONNEL:

A. Study Director: Brian Myhr, Ph.D.

B. Laboratory Supervisor: Robert Young

VII. RESULTS:

The data are presented in Table 1 on page 3 and in Figures 1 and 2 on pages 4 and 5.

VIII. INTERPRETATION OF RESULTS:

About 24 mg of test material was placed into 0.1 ml DMSO and sonicated. After sitting for 2-3 hours to sterilize and leach the material, the suspension was diluted into growth medium and applied to the cell cultures at a maximum concentration of 1000 µg/ml. The maximum DMSO concentration was 0.42%; this decreased with successive dilutions in growth medium. The negative control cultures did not contain DMSO.

None of the five assay parameters yielded EC50 values below 1000 µg/ml. Therefore, the test material is classified as having nondetectable toxicity to the macrophage cells. At all test concentrations, the numbers of cells (total or viable) were depressed slightly below the negative control. The reason for this small loss is unknown. The cell loss is probably responsible for the elevation in the ATP per 10^6 cells to values greater than the negative control level.

IX. CONCLUSIONS:

The test material, Stoker Fired Boiler #2, Boiler Bottom Ash, is evaluated as having nondetectable toxicity in the Rabbit Alveolar Macrophage Cytotoxicity Assay. The EC50 values for all assay parameters were greater than 1000 μg/ml.

Submitted by:

Study Director

Brian Myhr 2/26/79
Brian Myhr, Ph.D. **date**
Section Chief
Mammalian Genetics
Department of Genetics
and Cell Biology

Reviewed by:

2/26/79
David J. Brusick, Ph.D. **date**
Director
Department of Genetics
and Cell Biology

Litton BIONETICS

ACUTE ORAL TOXICITY STUDY IN THE RAT

STOKER-FIRED BOILER NO. 2 - BOTTOM ASH

FINAL REPORT

SUBMITTED TO:

ACUREX CORPORATION
485 CLYDE AVENUE
MOUNTAIN VIEW, CALIFORNIA 94042

SUBMITTED BY:

LITTON BIONETICS, INC.
5516 NICHOLSON LANE
KENSINGTON, MARYLAND 20795

LBI PROJECT NO. 21010 (1-A)

FEBRUARY 1979

Litton BIONETICS

SPONSOR: Acurex Corporation

MATERIAL: Stoker-Fired Boiler No. 2 - Bottom Ash

SUBJECT: FINAL REPORT
Acute Oral Toxicity Study in the Rat
LBI Project No. 21010 (1-A)

SUMMARY

The oral LD50 value of the test material was greater than 10,000 mg/kg for both male and female rats.

UCES Project No. 11507-03

Selenastrum capricornutum
Algal Assay
Testing

Stoker Fired Boiler No. 2
Boiler Bottom Ash

Prepared For

Acurex Corporation
Aerotherm Divison
Mountain View, CA 94042

Prepared By

UNION CARBIDE ENVIRONMENTAL SERVICES
Union Carbide Corporation
Tarrytown, New York 10591

April 2, 1979

I. SUMMARY

The alga Selanastrum capricornutum was exposed to nominal concentrations of Stoker Fired Boiler No. 2, Boiler Bottom Ash, for 17 days. Data subjected to a two-way logarithmic analysis of variance of the entire exposure period shows control productivity significantly lower than the nominal tested concentrations of 100, 180, 320, 560 and 1000 mg/l, by 4 to 15 percent. At no time did the test material impede algal growth compared to the control.

MUTAGENICITY EVALUATION OF
STOKER FIRED BOILER #2 ELECTROSTATIC PRECIPITATE HOPPER ASH
IN THE
AMES SALMONELLA/MICROSOME PLATE TEST

FINAL REPORT

SUBMITTED TO:

ACUREX CORPORATION
485 CLYDE AVENUE
MOUNTAIN VIEW, CALIFORNIA 94042

SUBMITTED BY:

LITTON BIONETICS, INC.
5516 NICHOLSON LANE
KENSINGTON, MARYLAND 20795

LBI PROJECT NO. 20988

OCTOBER 1978

Litton BIONETICS

I. SPONSOR: Acurex Corporation

II. MATERIAL*

A. Identification: Stoker Fired Boiler #2 Electrostatic Precipitate Hopper Ash

B. Date Received: July 20, 1978

C. Physical Description: Black powder

III. TYPE OF ASSAY: Ames Salmonella/Microsome Plate Test

IV. PROTOCOL NO.: DMT-100

V. RESULTS

The results of this assay are presented in Tables 1 and 2.

VI. INTERPRETATION OF RESULTS AND CONCLUSIONS

The test compound was examined for mutagenic activity in a series of *in vitro* microbial assays employing *Salmonella* indicator organisms. The compound was tested directly and in the presence of liver microsomal enzyme preparations from Aroclor-induced rats. The following results were obtained:

The compound was tested over a series of concentrations for mutagenic activity and for toxicity. The dose range employed for the evaluation of this compound was from 0.01 mg to 10 mg per plate.

The test compound did not exhibit toxicity with any of the strains at the dose levels employed in these assays.

The results of the tests conducted on the compound in the absence of a metabolic activation system were all negative.

The results of the tests conducted on the compound in the presence of a rat liver activation system were all negative.

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*Information was supplied by the sponsor. If the sponsor did not indicate this information, N.I. was entered.

VI. INTERPRETATION OF RESULTS AND CONCLUSIONS (Continued)

The test compound Stoker Fired Boiler #2 Electrostatic Precipitate Hopper Ash did not demonstrate genetic activity nor was it toxic at the doses employed in any of the assays conducted in this evaluation and was considered not mutagenic under these test conditions.

Submitted by:

Study Director

for Kulbir S. Bakshi 10/25/78.
D.R. Jagannath, Ph.D. Date
Section Chief
Submammalian Genetics
Department of Genetics
and Cell Biology

Reviewed by:

10/30/78
David J. Brusick, Ph.D. Date
Director
Department of Genetics
and Cell Biology